THE McGRAW-HILL MAGAZINE FOR DESIGN ENGINEERS

NOV 27, 1961

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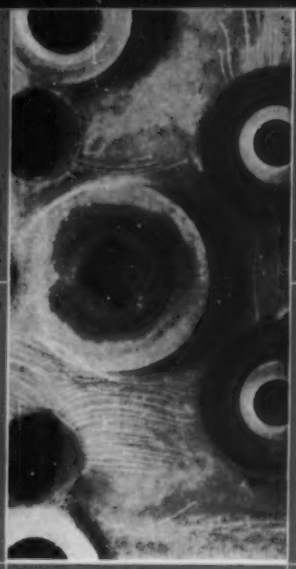

BRITTLE COATINGS

Simplest of the stress analysis techniques, here's how to select the best formulation, prepare test specimens and analyze crack patterns.

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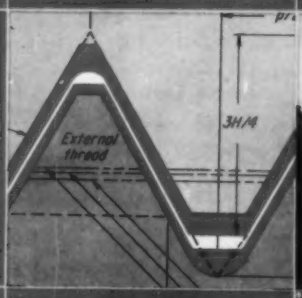
PRODUCT ENGINEERING

THREADS



Shear and tensile strengths for sizes from #0 to 6 in. for all classes and even for mixed classes of threads.

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PINCH VALVE

Rubber tube isolates irritating gas from control valve. Trigger stops flow by bending tube.

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VEHICLES

No drivers needed for these warehouse trucks, mine cars and buses. Passenger cars may be next.

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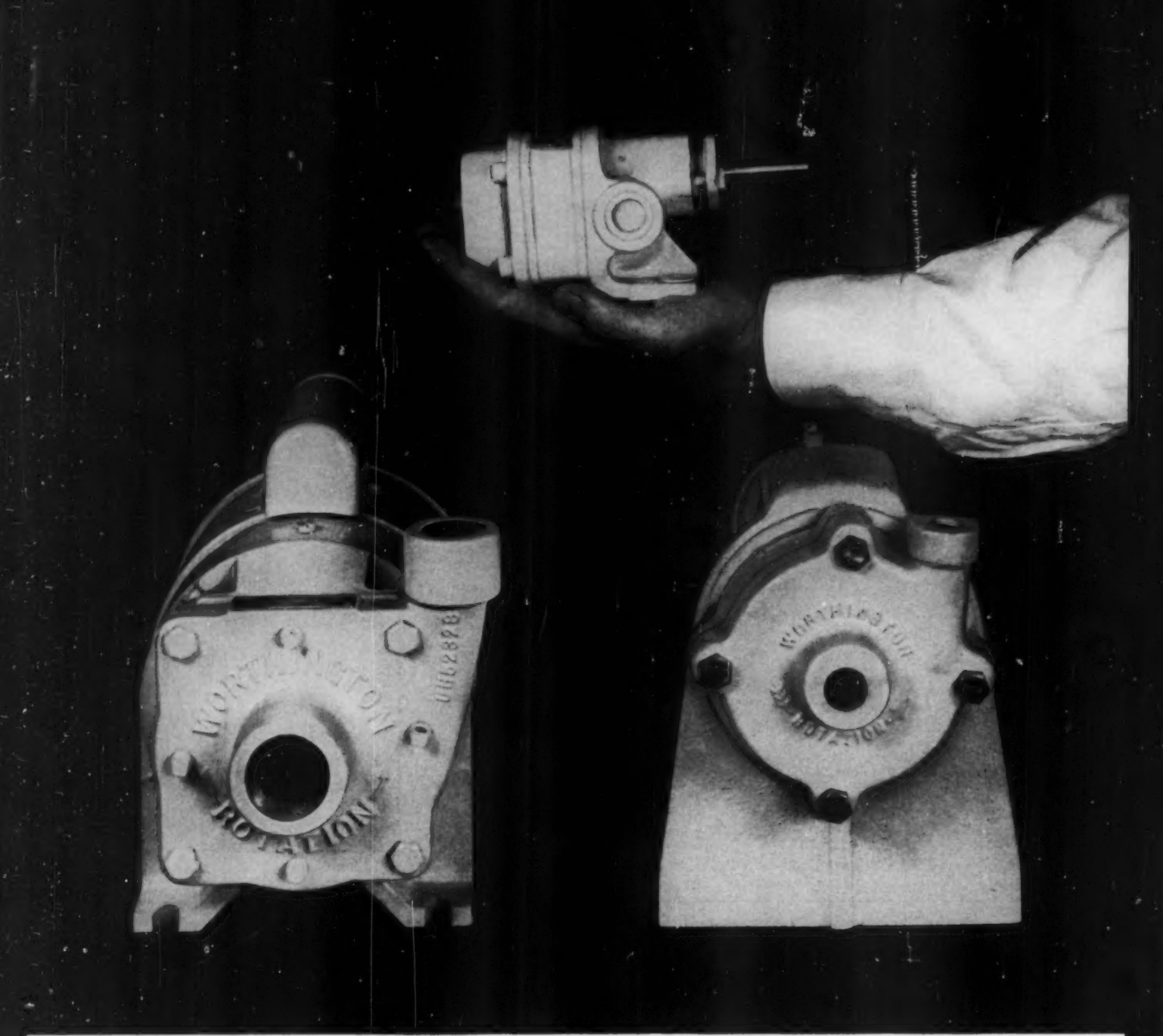

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PRODUCT

Table speeds calculation of thread strength 41

For sizes from #0 to 6 inches, from coarse to extrafine, for all classes and even for mixed classes of threads, here are computer-calculated shear and tensile areas for all internal and external threads. *Raymond C Boucher*

Metered oil feed ends hand mixing 50

Two-cycle auto engine has variable-volume oil pump to supply lube oil to gas intake manifold. Flow is modified by engine speed and load for optimum gas-oil ratio.

Pinch valve controls gas flow 52

Stream of irritating gas is isolated from the metal valve parts to eliminate contamination and corrosion of riot-busting gas gun.

Ball replaces a rack and pinion 52

Dial indicator uses linear-to-rotary motion transfer by ball bearing to give 0.000,02-inch repeatability.

Graphical analysis for cost control 54

You divide your production run into bands by cost and plot as a frequency distribution. Curve shape shows where production has gone wrong—and what to do about it. Works as well for drafting-room production as for the machine shop. *Hector E French*

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ENGINEERING

8 Push-pull linkages **56**

These basic arrangements are used in all devices where oscillating motion must be transferred between two components. *Frank W Wood Jr*

More data on hermetic magnetic couplings **58**

These are the devices that transmit torque right through the walls of an air-tight container. Recent tests have provided more accurate constants for the design equations. *Frank Yeaple*

Practical applications of driverless vehicles **60**

First step toward automatic highways, they're appearing as cable-guided buses, ore trucks and warehouse tractors. *Bruce Cross*

For stress analysis, brittle-coating methods **63**

Second in our continuing series on stress-analysis techniques, here's how to select the best formulation, prepare test specimens and analyze crack patterns. And for the first time in print—a new micro technique invented at Battelle. *Nelson A Crites*

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COMING NEXT ISSUE

Which electric brake?

Comparison tables and charts to help you select the smallest (and cheapest) brake to stop a load and dissipate the heat energy.

Overload margin in motors

Enclosed motors with class-B insulation now match class-A open motors in overload capacity. See what these better service factors can do for your design.

Creativity—still the will-o'-the-wisp

Research groups are probing and now they have some ideas about what creativity really is. An engineer also suggests that **Intuitive Engineering** is an essential creative task for designers.

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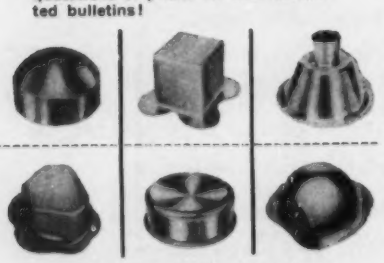

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INTERESTING TO NOTE

LIKE the old wheeze about the chicken and the egg the problem of cutting **the first screw thread** has puzzled many engineers. At first thought, the thing seems impossible; you can't cut a screw without some means of moving the tool at a fixed rate and you can't move the tool without an existing screw to drive it. But, as many an old-time machinist knows, there are several ways to cut threads without a lead screw.

Probably the easiest is with a tool having two or more cutting points. The tool is ground with an appropriate amount of front clearance and side lead and the two points brought to bear against the cylindrical surface of the work. When starting the thread, the tool is allowed to track forward with just the right speed so that the trailing point falls in the grove made by the leading point after one revolution. (If the tool has been ground properly, it should do this without help from the machinist.) From there on it is simply a matter of allowing the trailing point to feed the tool forward as it rides in the groove cut by the leading point.

Thread chasing, the proper name for this process, is still practiced in industry when the lath at hand is not equipped to turn the needed thread. The trick has been a source of much amusement to machinists who delight in betting a naive bystander that they can cut 64 threads to the inch on a lathe whose gears go only to 40. He simply breaks off the shank of a 64-thread tap and chases the thread holding an exposed flute against the rotating stock.

Another way to cut a thread without a master is to hand file it from a steel rod. The pitch is determined by cutting a paper triangle of the proper dimensions, and wrapping it around the rod in such a way that the base of the triangle is parallel to the rod's axis. The wrapped edge then forms a pattern which can be transferred to the steel with a file or a hacksaw . . . and plenty of elbow grease. If the rod is made of tool steel (in which case, you'll need even more elbow grease) only a few revolutions of the thread need be cut. These few threads can be used as a tap to cut matching threads in a spilt die and the die, in turn, used to cut the remaining threads on the rod.

The wrapped paper triangle (sometimes it was simply a strip of paper wrapped at an angle) has the longest history and was undoubtedly the method used to generate the wooden threads found on Greek and Roman presses. But when Henry Maudsley came to cut threads for his original engine lathe in 1800, he turned to still another method. Screw threads had been cut in metal as early as the 14th century but were generally not accurate enough for the application Maudsley had in mind. To generate more accurate threads, Maudsley used a crescent shaped knife which he held against a hardwood cylinder at a precisely defined helix angle so that rotation of the cylinder would cause the knife to move along the cylinder. He then copied these threads in steel. By this method, he was able to make screw threads accurate to 0.0001in.

Maudsley's lead screw had square threads. Indeed, most of the threads cut in metal up to that time were square following Benevenuto Cellini's advice in a treatise on goldsmithery, "square threads are stronger than those made in the other, ordinary way" (whatever that may be). The strength of modern threads can be calculated with the help of the table in the article on thread strength which begins on page 41.

Stress testing the hard way

On May 2, 1953 a BOAC jet airliner roared down a runway at Calcutta's Dum Dum Airport and lifted off into the gray sky headed toward New Delhi. Six minutes later while cruising at 10,000 feet, the plane mysteriously went to pieces, scattering wreckage over an area of five square miles. This was the first of three disasters involving the de Havilland Comet I, the first jet airliner to see commercial service. It set off a series

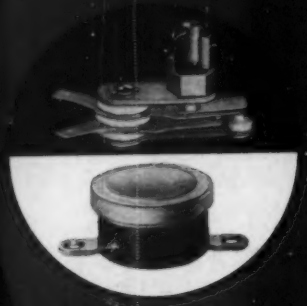
continued, page 6

CIRCLE 4 ON READER SERVICE CARD
CIRCLE 5 ON READER SERVICE CARD→

I

OF A SERIES *NOTES FROM A DESIGNER'S SKETCH BOOK*

STEVENS *Table Appliance** THERMOSTATS



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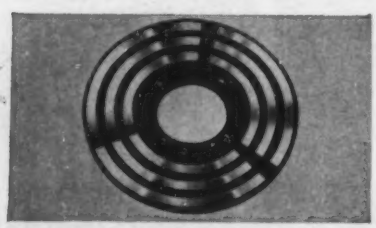

The second basic type, a pancake ring assembly, with segmented rings of varying diameters.

SUPERIOR CARBON PRODUCTS, INC.
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INTERESTING TO NOTE *continued*

of tests and enquiries which lasted for over two years and subjected the aircraft to the most strenuous tests ever performed on a civil airliner.

De Havilland engineers were admittedly puzzled. Apparently the planes were disintegrating in mid-air but they could offer no explanation for the breakup. The de Havilland company, too, faced a severe bind. With the air-worthiness certificate on the Comet I's withdrawn, authorities refused to grant a certificate to Comet II's coming off the assembly line or to Comet III's then taking shape. All production came to a grinding halt.

Engineers began a series of tests. First, they put a Comet on a static test stand and applied simulated flight loads with the hope that something would come unglued. After 150,000 hours, they were unable to find a single structural failure. Next they completely disassembled the plane and examined each part for evidence of incipient structural failure. Nothing was found.

The most extensive testing was done in a water tank large enough to enclose the plane's fuselage. The purpose of the tank was to test the fuselage at pressure differentials equivalent to those of a pressurized cabin in flight. The water protected personnel from flying debris in case anything should let go.

While the experiments with the water tank were going on, wreckage of a Comet that had gone down near the island of Elba, the only wreck whose pieces could be recovered, were being returned to England and painstakingly reassembled on a special skeleton framework. First came the engines and scraps of the wing. Then came bits and pieces of the fuselage. Most of the cabin, from the main wing spar to the rear pressurization bulkhead was in pieces no larger than one foot square. Several theories of the mysterious disintegration were proposed. To test the theories, engineers made $\frac{1}{32}$ scale models which had critical pieces held on with pins and bits of string. These were shot at 100 mph from a catapault track on the top of a hangar and allowed to "crash". Comparing the distribution of the wreckage with that of the Elba crash produced clues to the cause of the disaster.

The first break in the case came early in July 1954, three months after the Comets were grounded. While inspecting the partially assembled corpse of the Elba plane, an engineer noticed a long spanwise scratch in the upper wing panel. Apparently something had been expelled from the cabin with a force great enough to skitter it along the wing for several yards before being swept back by the slipstream. The errant missile, however, was not among the pieces of the wreck. Three days later, the submerged fuselage in the test tank let go with a roar, ripping a gaping 30-ft hole in the fuselage over the wing. The break had occurred, starting from a fatigue crack in the corner of a direction-finder "window" in the top of the fuselage. The fuselage was patched with new parts and tested again. The second break occurred in the same place.

By August 1954, engineers had compiled enough evidence to point to the exact cause of the mishap and the sequence of events. The missing piece of the fuselage, one of the last pieces to be recovered was dredged up from the sand near Elba. It matched the long scratches on the wing and bits of paint from the BOAC markings on the wing were found imbedded in the sharp edges that had caused the scratch.

The de Havilland case is an extreme example. Usually experimental stress analysis and discovery of incipient fatigue failures requires only inexpensive tools and materials. For an explanation of one of the quickest and least expensive stress tests, see the article on **brittle coatings** which begins on page 63.

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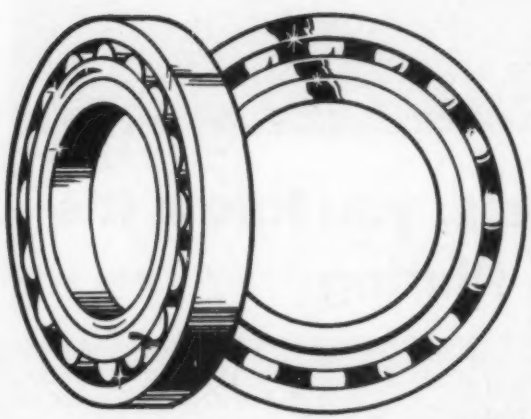

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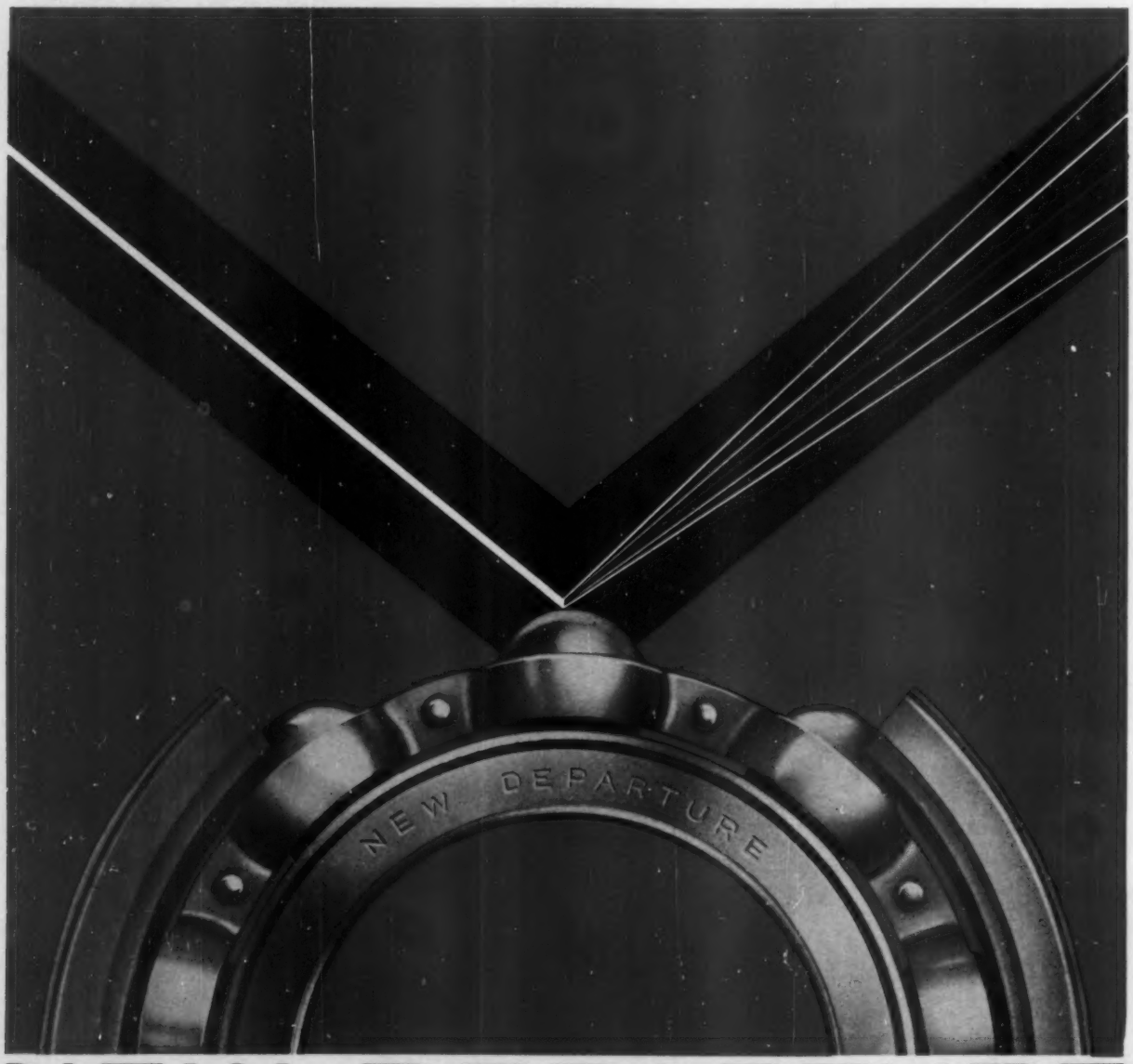

NEW DEPARTURE

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HORIZONS

The seats of the mighty

IN NEW GUINEA—about as primitive as any area of our modern world—the chief is distinguished by his elaborately carved war club. Raise the level of civilization just a little, and the chief has a throne. His status is indicated by the fact that he sits down while everyone else stands, bows, grovels, or whatever. You will recall that King Canute had his throne brought out to make his command to the sea authoritative, that the Stone of Scone has been placed within the throne chair at Westminster, and so on.

Sitting down is still the symbol of rank. The elaborate chair still signals the executive; the right to sit down was until recently the other distinction of the white-collar man. When labor groups wanted to embarrass management, they sat down; when the Negroes became active in the integration battle, much of the furore was caused by their assumption of the right to sit down —in lunch rooms, schools, buses. In Jackson, Miss., the mayor ordered parkbenches removed because Negroes sat on them. The animals, who sit where and when they will, must have been somewhat amused.

BUT THE SUPPORT PROBLEM . . .

This is the aesthetic aspect of seating. Two others concern engineers more. One is to rest the weary (?) bones of operators of everything from automated machines to automobiles and involves judicious study of the gluteus maximus to ease or prevent its protests. This has gone far in this age of comfort, even overseas. Among a dozen papers on seating at a recent Chicago meeting of the Human Factors Society, Dr. Heinrich Dupuis reported studies on tractor vibration at Max Planck Institut in Germany. It seems that vibration-sensitive drivers develop occupational physical disabilities. Of 233 drivers studied, 76% developed ill effects in the stomach, gastroptosis (depression) as well as gastritis (inflammation of the mucous membranes).

Tractor seats are designed for medium-weight drivers, so light drivers (usually young people) are endangered because their bodies are still developing, while the spines of heavier people are damaged by inadequate support. So some American tractors now have adjustable seats. Watch the decline of the old-fashioned stool and hard chair after this report! President Kennedy's tricky back and the resulting publicity for Doctor Travell's advocacy of the old-fashioned rocking chair have had, and are having, their effects too.

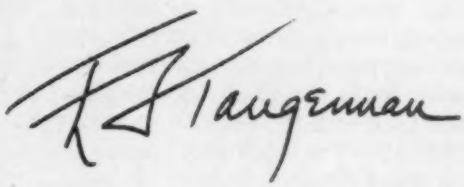
The Air Force has been working out basic principles of seating, now has a machine that contour-charts seat pressures. (It is called, inelegantly, the "Buttock-scope.") As a result of these studies a seat has been designed that was comfortable to a pilot for 80 continuous hours, an essential in the early stages of orbiting a man.

TESTING TRADITION

From where I sit, however, these elements pale into insignificance beside the growing appreciation of the seat as a hypersensitive testing instrument. Everyone knows the sensitivity of the seat to heat, cold and dampness; one of the oldest gestures of civilized man has been to turn his seat to the heat. We have already reported its use in locating submarine cables (*PE—Apr* 10 '61 *p* 28) and excessive vibration (*PE—Mar* 13 '61 *p* 29). There is also the tale of the Scotsman with the calibrated pantaloons who was better than any testing device at an English shock-absorber plant, sworn to by no less an authority than the former plant manager, who is now a respected engineering professor at Brooklyn Polytechnic Institute.

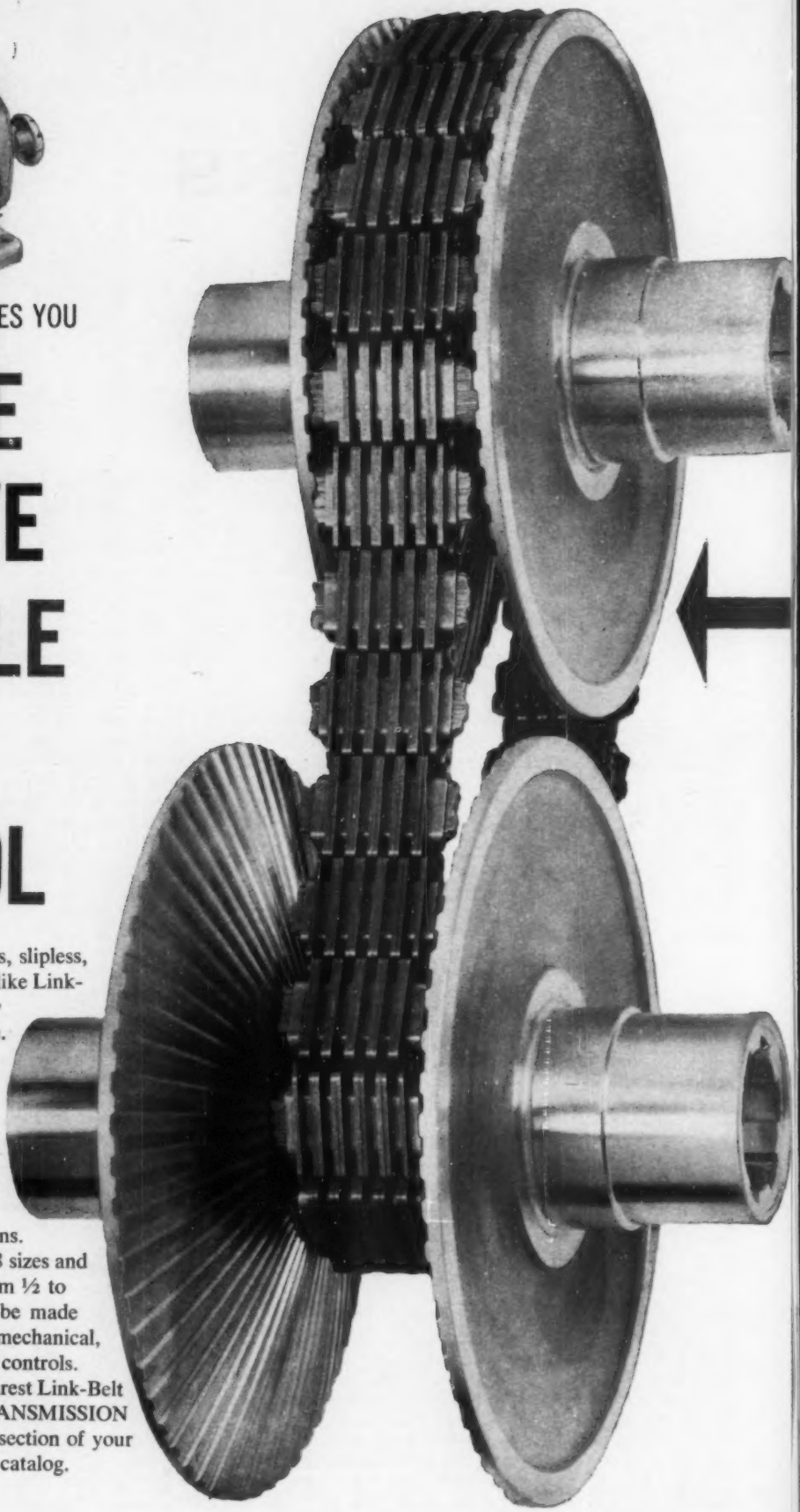
Thus the seat, in addition to creating aesthetic concern because it is callipygian or steatopygic (and some rather elaborate two-way stretch engineering has been concerned with THAT problem), seems to be the seat of many of our ills if the engineer does an inadequate job of supporting it, and is still superior to available instruments in some kinds of sensitive testing.

This suggests that we sit down and study the subject with as much engineering as aesthetic interest. Could this be the area of integration of the "two cultures" we've heard so much about?



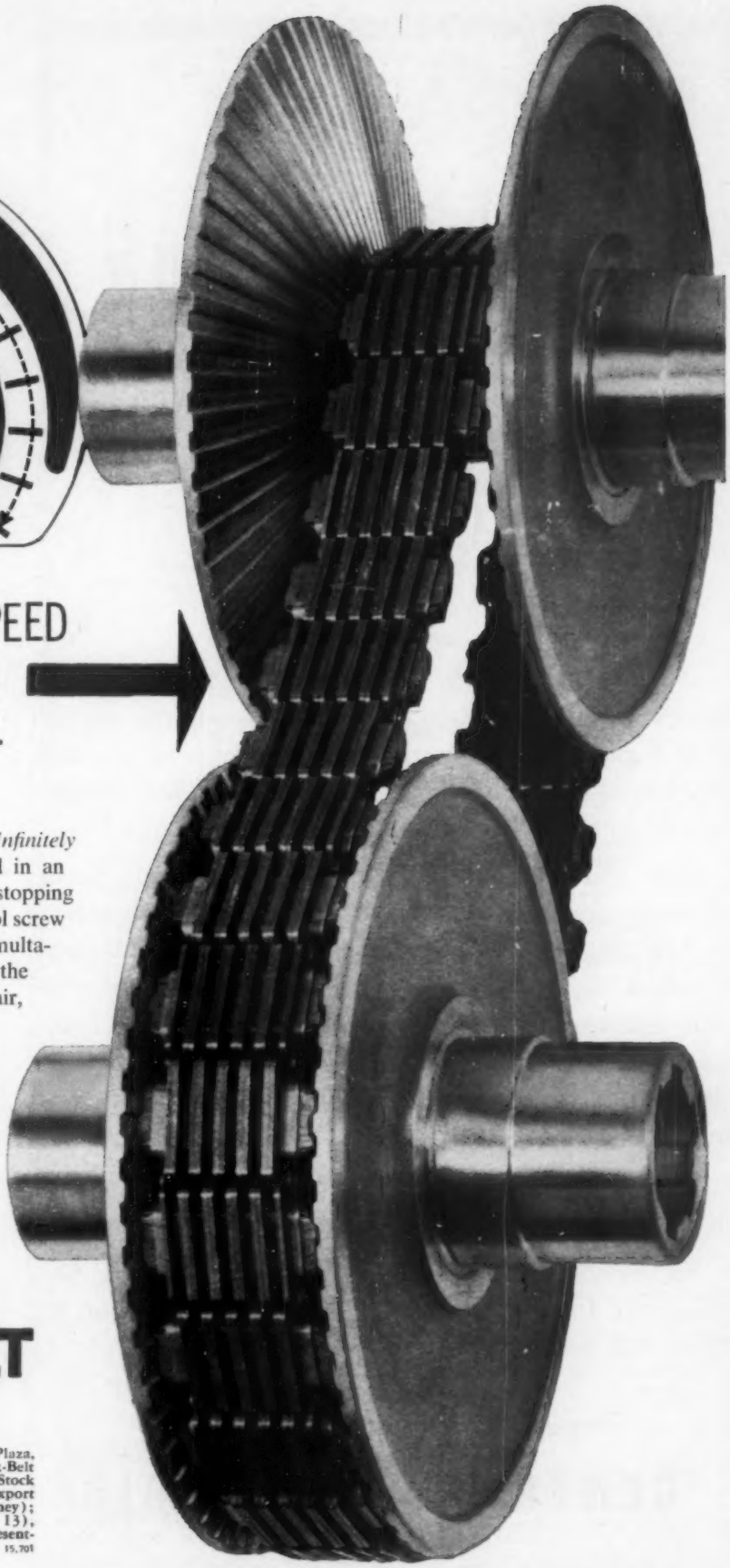
LINK-BELT
CHAIN DRIVEN P.I.V. GIVES YOU

PRECISE POSITIVE VARIABLE SPEED CONTROL



For operations requiring stepless, slipless, speed-changing, there's nothing like Link-Belt's P.I.V. . . . industry's *only chain-driven* variable speed drive. Unusual speed control accuracy results from P.I.V.'s unique design featuring *wheels and chain with teeth.* The two pairs of conical wheels act as gears . . . mesh with self-tooth-forming chain to assure positive contact under all speed and load conditions. Link-Belt's P.I.V. line includes 8 sizes and 16 standard types, capacities from ½ to 25 hp. Speed adjustments can be made manually or automatically with mechanical, hydraulic, pneumatic or electric controls. For full details, contact your nearest Link-Belt office. Look under POWER TRANSMISSION EQUIPMENT in the classified section of your local phone directory. Send for catalog.

P.I.V.®
LINK-BELT



FROM MINIMUM SPEED TO MAXIMUM SPEED

NO SLIPS... NO STOPS... NO STEPS IN BETWEEN

With a Link-Belt P.I.V.—*Positive, Infinitely Variable*—drive, speeds can be varied in an instant, regardless of load and without stopping the driven machine. A turn of the control screw changes the speed. The control screw simultaneously varies the effective diameters of the conically shaped wheels—closing one pair, spreading the other. This automatically, *instantly* adjusts the chain to provide a controlled output speed. Slippage? Not a chance—P.I.V.'s chain-to-wheel grip is positive as a gear.

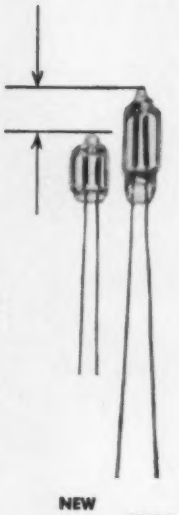
LINK-BELT

P.I.V. VARIABLE SPEED DRIVES

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Warehouses, District Sales Offices and Stock Carrying Distributors in All Principal Cities. Export Office, New York 7; Australia, Marrickville (Sydney); Brazil, Sao Paulo; Canada, Scarboro (Toronto 13), South Africa, Springs; Switzerland, Geneva. Representatives Throughout the World. 15,701

CIRCLE 13 ON READER SERVICE CARD

SAVE 1/4 INCH WITH THIS NEW TINIEST GENERAL ELECTRIC GLOW LAMP



Here's an indicator light that's only two-thirds the size of G-E glow lamps formerly available. Yet it lasts as long and has equal brightness. It's available as a high brightness lamp (A1C) and a standard brightness lamp (A1B).

This new General Electric glow lamp packs 5 mm electrodes into an M.O.L. of ½". Its maximum diameter is .244". It operates on standard line voltage, and because it uses a higher value resistor than a conventional glow lamp, it runs on half the current. This ½" long lamp, therefore, has a reduced total light output but because its brightness is not reduced, it is just as effective an indicator as other glow lamps in most applications.

You can get this new glow lamp for less than 5¢ each in lots of 25,000. (Slightly more with a resistor attached.)

For complete information write: General Electric Co., Miniature Lamp Dept. M-151, Nela Park, Cleveland 12, Ohio. Ask for Bulletin No. 3-1504.

Progress Is Our Most Important Product

GENERAL ELECTRIC

READER TO EDITOR

Pre-Soviet Soviets

To the Editor:

It is shocking to find that the Soviets' propaganda war has successfully penetrated the editorial columns of PE. In the October 2 issue (page 11) you credit them with building a typewriter in 1840, and caption a cut as showing Soviet carts in 1903. Did the USSR exist then? Or was it Russia? I certainly hope it is not a case of infiltration! —HOMER S DAVIS
Los Angeles, Calif

It was a case of non-filtration; nobody sifted out the modern word "Soviet" in the copy, so in this case the Soviets were credited for Russian accomplishments—quite a switch! A somewhat similar situation has been uncovered by two alert readers in "The Great Paper Robbery," in the Interesting to Note column for Aug 28. There is some debate about who actually discovered paper, but one school holds that it was the Bactrian tribe in Afghanistan—and the Chinese stole it from them! Further, there was no mention of a Moskau until the twelfth century, and first traces of organized living were in the Kiev area in the middle of the tenth, so Russians obviously couldn't have been at war with China in 751, as our story had it. There is a story that Muscovites (from the heartland of what became Russia) sacked Samarkand one summer while Tamerlane (1336?-1405) was fighting the Persians or Hungarians, and that he made forced marches on his return to catch them and annihilate the raiders. Be all that as it may, the Russians stole no paper secret from China in 751 AD—there was a broad expanse of flat land and some mountains populated by fierce Mongol tribes between China and any Moscow there might have then been. In the middle of the eighth century, China was at war with the Arab nations—probably Persia—so it was likely the Persians who wormed out the secret. In any case, our word paper comes from "papyrus" which is as far as I know, a Near East sedge, from the pith of which the Greeks, Romans and Egyptians produced a crude form of plaited paper. —**EJT**

Other-world Gear Tolerances?

To the Editor:

I have read with interest your article entitled "New AGMA Classification System for Gears" (*PE—July* 10 '61, *p* 68). I would like to bring to your

notice a similar specification that now exists in England, 'Precision Gearing for Control Systems and Armaments,' BR 6001/1 by an Admiralty Working Party, available from Her Majesty's Stationery Office. In my humble opinion it would seem that this specification has certain advantages in presentation and is a little more definite in its approach. Further, some of the tolerances quoted in the AGMA would appear to be out of this world and it is suggested that rather than increase the difficulties of the already hard-pressed manufacturers, error-compensating devices be employed, allowing wider manufacturing tolerances but obtaining similar results at far less cost.

—RAYMOND V THOMPSON
Stevenage, England

Correction:

In **Critical Speed for Vibration** (*PE—Sep* 4 '61, *p* 215), $p = (w\omega^2/gEI)^{1/4}$, w = weight of shaft per unit length; equations for D_1 and D_2 should be, respectively: D_4 [cos *bpl* . . . etc, and $-D_4$ [cos *bpl* . . . etc.

COMING EVENTS

DECEMBER

4-5 . . . . New York Univ, Conference on Beryllium Metallurgy, College of Engineering, University Heights, New York City

12-14 . . . . Institute of Radio Engineers, AIEE, ACM, Eastern Joint Computer Conference, Sheraton Park Hotel, Washington

JANUARY

8-12 . . . . Society of Automotive Engineers, Automotive Congress & Exposition, Cobo Hall, Detroit

9-11 . . . . Institute of Radio Engineers, 8th National Symposium on Reliability & Quality Control, Statler-Hilton Hotel, Washington

28-Feb 2 . . . . American Institute of Electrical Engineers, Winter General Meeting, Statler-Hilton Hotel, New York City

29-Feb 1 . . . . American Society Heating, Ventilating, Air Conditioning Engineers, Semi-annual meeting, Chase Park Plaza Hotel, St. Louis

For a listing of addresses of societies and associations send 25¢ to Product Engineering Reader Service Dept, 330 W 42nd St, NY 36. Ask for brochure R 32.

GRIPCO GUS
expands the gang...

Have you met hard workin' GRIPCO GUS? His job is finding the best nut for *your* application—and that naturally includes developing new ones from time to time. His latest brainstorm is a particularly good example of this continuous service. More important, it's a particularly good *nut*. Take a look:

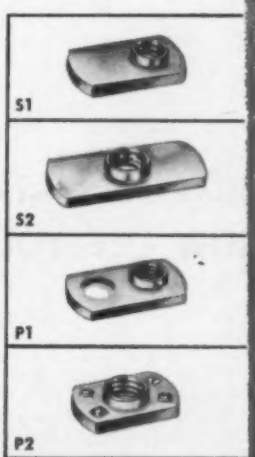
The New GRIPCO* TAB WELD NUT

S1 (Spotweld Type) Single weld area for applications where space is a factor.

S2 (Spotweld Type) Double weld area for maximum strength.

P1 (Pilot Projection Type) Single weld projection.

P2 (Pilot Projection Type) Four weld projections, eliminating rocking during welding operation and to give a maximum weld.



All offering:

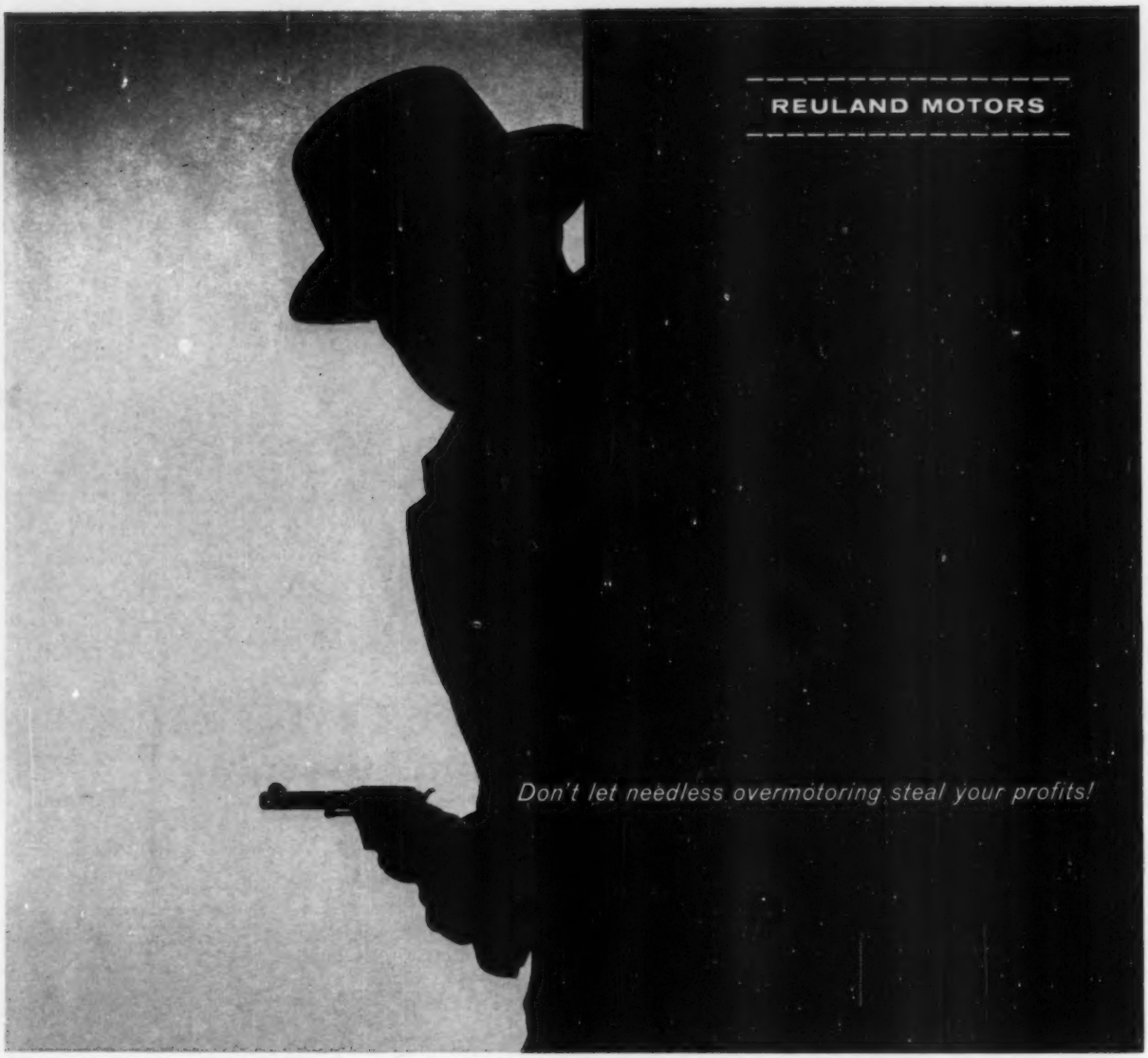
- Self-locating pilots for fast, accurate positioning—no locating devices needed.
- Convenient location of pilots and projections —no retapping required.
- Fast, clean welding—minimum current, short time-cycle.
- High welding quality, low carbon steel construction.
- Optional self-locking feature—the exclusive GRIPCO Toplock.
- Complete range of sizes available for immediate delivery from stock.

Get the full details on the new GRIPCO Tab Weld Nuts—including data on welding set-ups and complete price information—from *your* GRIPCO GUS. You'll find him listed in the Yellow Pages under "Bolts & Nuts" as the local GRIPCO Representative.

*GRIPCO is a registered trademark of Grip Nut Co.

GRIP NUT COMPANY
Subsidiary of Heli-Coil Corporation, Danbury, Conn.
911 Maple Ave. • South Whitley, Ind. • Phone: South Whitley 723-5111

3136



NEW REULAND INTERMEDIATE HORSEPOWER RATINGS NOW LET YOU BUY JUST THE H.P. YOU NEED!

Reuland's 13 new, *"intermediate"* horsepower ratings let you now choose motor sizes in between conventional N.E.M.A. ratings... help you cut motor costs by buying only the horsepower you *need.* No longer must you pay for needless overmotoring... no longer must you buy horsepower you can't use!

Typical examples of savings are the new 32½, 35 and 37½ H.P. ratings in between the standard 30 and 40 H.P. gap. Others are spaced at intervals between 2 and 60 H.P., and priced accordingly.

In addition to reducing basic motor costs, savings are also often gained on lower rated components such as gear boxes, couplings and controls. Compactness and lighter weight are further advantages.

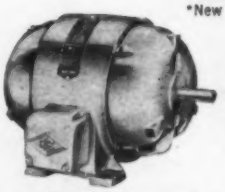
Reuland *"intermediate"* ratings have application in almost every industry... wherever a machine's performance curve indicates a required H.P. in between conventional motor sizes. Why not check to see what these new *"intermediate"* ratings hold in store for *you!*

MODERN POWER FOR MODERN-DAY PRODUCTS
...all in lightweight, cool-running aluminum frames!

28 horsepower ratings from ¾ through 60 ...13 brand new exclusive intermediate ratings!

¾	1	1½	2
2½*	3	4*	5
6¼*	7½	8¾*	10
12½*	15	17½*	20
22½*	25	27½*	30
32½*	35*	37½*	40
45*	50	55*	60

*New intermediate ratings



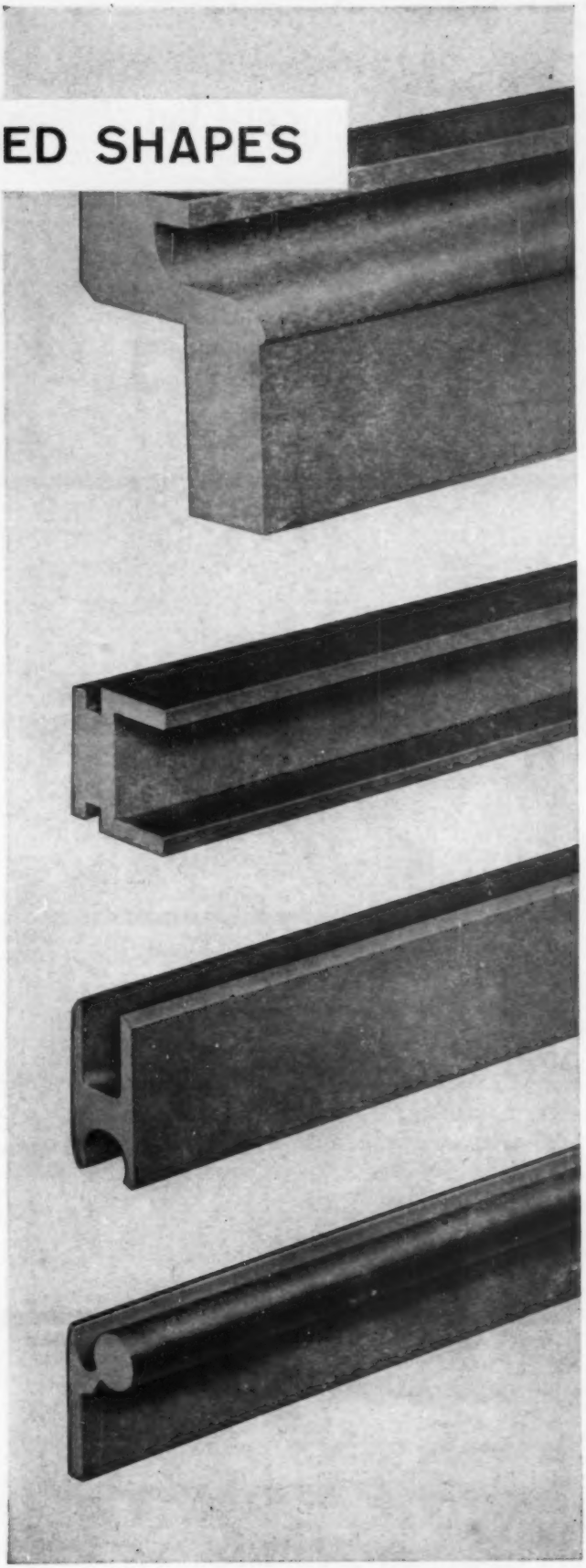
Your copy of this new catalog on the complete Reuland line will come in handy. Sent free on request.

REULAND MOTORS

REULAND ELECTRIC COMPANY
WESTERN DIVISION: ALHAMBRA, CALIFORNIA
EASTERN DIVISION: HOWELL, MICHIGAN
DISTRIBUTORS IN ALL PRINCIPAL CITIES

ANACONDA EXTRUDED SHAPES

when you want extra strength . . . when you need longer wear!



When you are called upon to incorporate performance characteristics such as these, to a greater degree than is provided in parts made from sand castings, consider Anaconda Extruded Shapes. Parts cut from extruded shapes *are* superior in quality and *do* improve the strength and durability of your finished product.

Anaconda can provide long lengths of preformed shapes exactly suited to your design requirements. Parts made from these extruded brass shapes are characterized by their strong, homogeneous, wrought-metal structure. What's more, the smooth, extruded surfaces also reduce many finishing operations—additional savings for you.

More and more manufacturers *design* extra strength and longer wear into finished products by using these preformed shapes. Let our technical service personnel lend practical—and imaginative—help in adapting extruded shapes to the economical production of intricate parts.

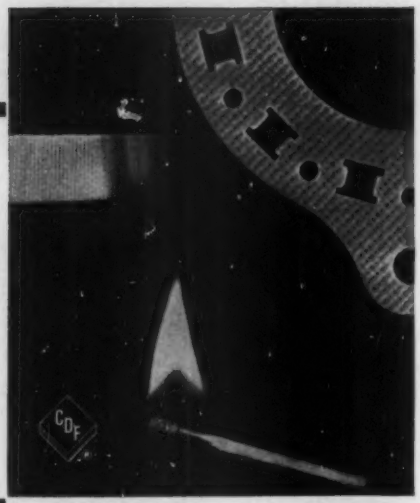
Publication B-37 supplies full facts on Anaconda extrusions in various alloys. Call your Anaconda representative or write: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 61-1119

EXTRUDED SHAPES

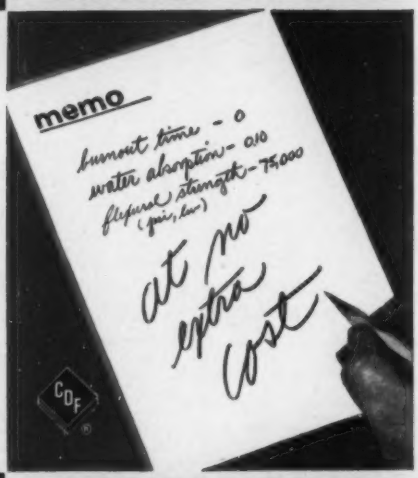
ANACONDA®

AMERICAN BRASS COMPANY

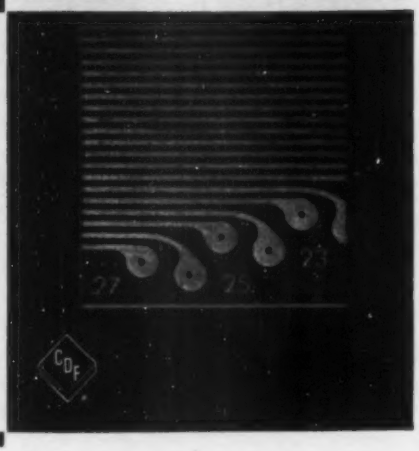
New Copper-Clad *Reliability*



In March, 1961, CDF Grade 614, glass-epoxy laminate, was announced . . . and met with almost overnight acceptance. Particular electronics and electrical manufacturers wasted no time in specifying this premium performance material with zero burnout and minimum "haloing."



By June, 1961, CDF Grade 614 had become the new standard of comparison for applications in critical ground and air-borne circuitry. Designers like its specifications, production men like the way it handles, management likes its reasonable price.



Now, CDF Grade 614 Copper-Clad is setting a new pace among particular producers of printed circuits . . . offering a new high in reliability for high packaging densities . . . and offering researchers a new tool in the investigation of molecular and submicro-circuitry.

You can take advantage of 614 Copper-Clad's unique features right now . . . in research, development or production operations. Continental-Diamond Fibre Corporation, Newark, Delaware. A Subsidiary of the Budd Company.

ALLEN-BRADLEY SELECTS Flexonics BERYLLIUM COPPER BELLOWS

for longer life . . . higher pressures

Beryllium copper was selected as the metal for the Flexonics bellows in the new Allen-Bradley Bulletin 836 Style T Oiltight Pressure Control. Advantages gained include . . . longer cycle life . . . ability to withstand higher pressure . . . and negligible hysteresis for up to 80% of compression stroke. Specifications of the Allen-Bradley Style T Pressure Control are: Adjustable range 0 to 35 psi . . . adjustable differential 1½ to 7 . . . maximum allowable pressures 60 psi (line), 80 psi (occasional surge).

OTHER FLEXONICS BELLOWS

FLEXONICS CAN HELP YOU. If you are confronted with a problem involving absorbing, compensating, transmitting, or converting energy or force, your answer may well be a bellows. A good source of counsel is the Flexonics Application Engineering Staff. These men are experienced in all areas of bellows application from the simple sensing device of the domestic range to highly intricate and delicate fluid metering controls for missile engines. Flexonics bellows can be furnished in a broad range of metals. You are invited to submit your problem for analysis—without obligation.

B-840

Flexonics

DIVISION OF CALUMET & HECLA, INC.
386 East Devon Avenue • Bartlett, Illinois

FLEXIBLE METAL and SYNTHETIC HOSE
EXPANSION JOINTS
BELLOWS • SPECIAL TUBULAR ASSEMBLIES

In CANADA
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Bartlett, Illinois

Please send my personal copy of Flexonics 20 page Bellows Design Guide covering in detail Flexonics products and services for bellows applications.

Cosco Stools, Tables, Carts are . . .

"Made Like A Million" with Pittsburgh Steel Sheet

Make your products "like a million" and you'll sell them by the million.

That's the philosophy practiced at Hamilton Cosco, Inc. of Columbus, Indiana, manufacturer of nationally known Cosco brand tubular steel frame household and juvenile products and office chairs.

And the philosophy has paid off.

Introduced 16 years ago, Cosco household stools have averaged nearly a million units a year. Their success led to development of other popular Cosco products ranging from baby jumpers to executive office chairs.

Pittsburgh Steel Company plays an important part in Hamilton's success by supplying substantial quantities of cold rolled sheet that consistently meet Cosco's ultra-critical requirements.

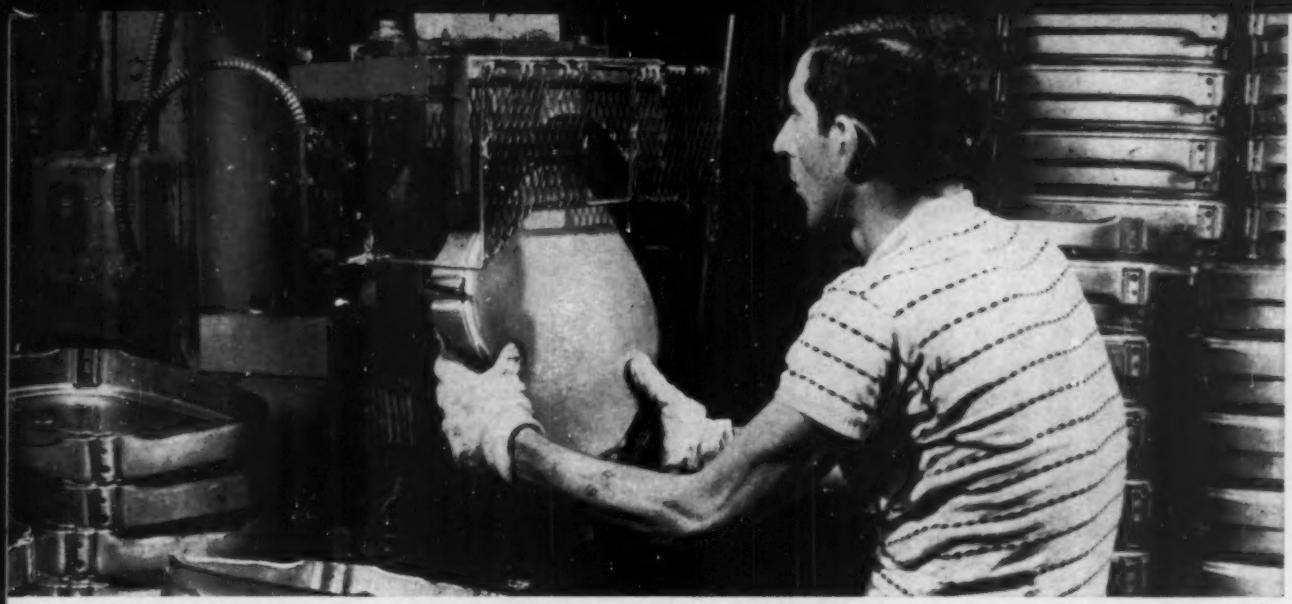
For, at Hamilton there's no such thing as a "second" in a finished product, be it serving cart or stool, playpen or folding bridge chair. The slightest imperfection — in forming, bending, painting or plating — requires reprocessing or scrapping of the defective item.

Supplying cold rolled sheet that faithfully meets such air-tight quality control places unusual responsibility on the steel supplier.

But, Pittsburgh Steel regularly meets this obligation with sheet known throughout the metalworking industry for its three "F" qualities:

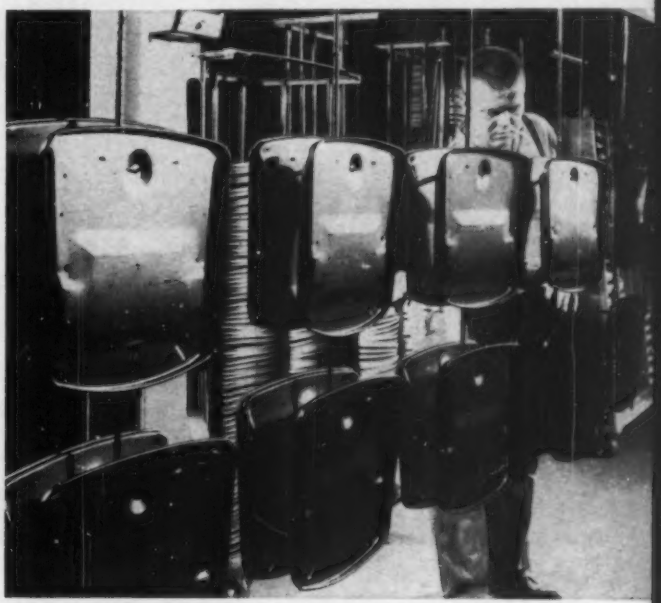
- **Flatness** — for exposed surfaces where appearance is vital and for fast production on automatic and semi-automatic equipment.
- **Finish** — dense, exceptionally clean surface for critical finishing operations, particularly Hamilton's electrostatic painting process.
- **Formability** — for precise uniformity in stamped, drawn, rolled or bent shapes; and especially for non-fluting characteristics in difficult bends on electric-welded tubing rolled

◀ The three "F" features of Pittsburgh Steel sheet—**flatness, finish, formability**—show up in assembly of the popular Cosco "Hour Glass" step stool. Gleaming backrests, gracefully curved tubular legs and brackets, seat pans and fold-away steps, all reflect quality of Pittsburgh cold finished sheet.



Flatness of Pittsburgh cold rolled sheet is critical for appearance, rigidity of stool seat and for trouble-free production in long runs. Here, after forming and piercing, raw edges are turned under.

Formability of Pittsburgh Steel sheet is demonstrated here as ¾ inch tubing, rolled from slit sheet, takes severe bends and deformation required for backrest brackets. Non-fluting quality of steel on radius of bends is vital on this and all other tubular parts produced by Hamilton Cosco, Inc.



Finish of Pittsburgh Steel sheet provides dense, exceptionally clean surface for tight, smooth paint adherence required by Hamilton's electrostatic painting process. Seat pans for Cosco's unique gatefold card table chairs show painting quality of steel.

from Pittsburgh Steel sheet.

H. E. Spurgeon, purchasing agent, said:

"The company's success is based on its insistence on absolute quality of its products—and that means quality starting with raw steel. We do many things merely because it's the best way.

"Performance of Pittsburgh sheet is very good, we've found. Over-all, I'd say Pittsburgh Steel is a very satisfactory supplier."

Pittsburgh Steel Company sheet—the steel with the three "F" qualities—can help step up your product quality, too, whether you're using hot rolled or cold rolled, sheet widths or strip widths. Contact one of the Pittsburgh Steel Company District Offices listed here. We'll match the steel to your product.

Pittsburgh Steel Company

Grant Building • Pittsburgh 30, Pa.

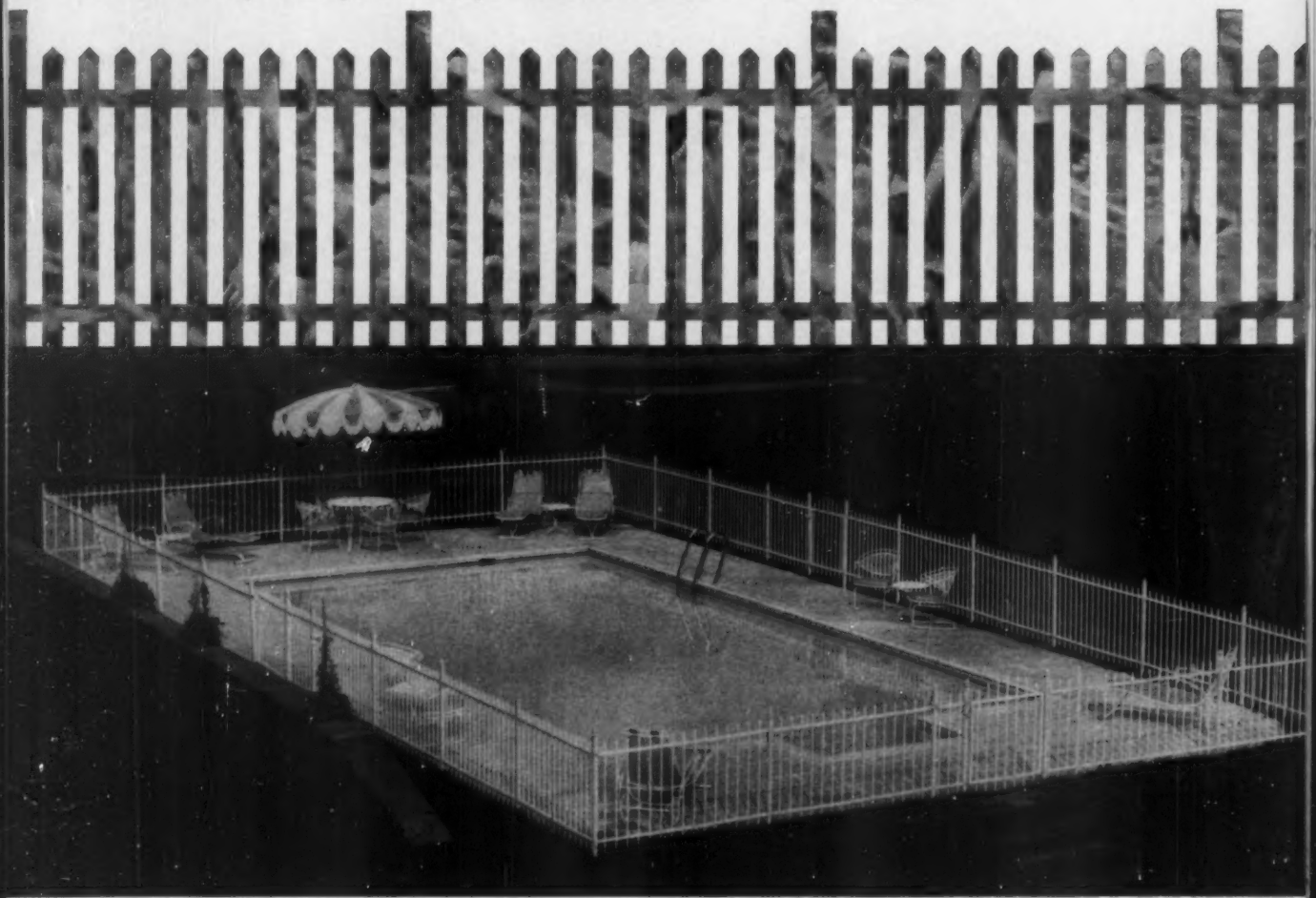
DISTRICT SALES OFFICES

Atlanta	Cleveland	Dayton	Los Angeles	Pittsburgh
Chicago	Dallas	Detroit	New York	Tulsa
		Houston	Philadelphia	Warren, Ohio

Steel

CIRCLE 21 ON READER SERVICE CARD

The rich look of wrought iron, yet Westmoreland's new fencing is . . .



GUARDED BY GALVANIZED STEEL

You're looking at an attractive new idea in fences from Westmoreland Metal Manufacturing Company of Philadelphia. It's a steel fence made of square tubing which duplicates the traditional appearance of wrought iron. But it costs less and virtually eliminates maintenance problems.

It's made of galvanized steel, which means lasting protection from the punishing whims of Old Man Weather. Come rain, come snow, the zinc coating stays on guard for keeps. Galvanized steel also helps hold down the price of this fence because of its low initial cost and the ease with which it can be formed into desired shapes.

WEIRKOTE® IN PARTICULAR! The galvanized steel used in this new fence line is National Steel's Weirkote. To the inherent strength, economy and versatility of steel, Weirkote adds enduring zinc protection via the modern continuous process. As a result, Westmoreland president, Irving H. Kutcher, reports: "Weirkote comes through our fabricating operation without any harm whatsoever to its protective zinc coating. We never have to worry about chipping or peeling." Weirkote is manufactured by two National Steel Corporation divisions, Weirton Steel and Midwest Steel. Write Weirton Steel, Weirton, West Virginia, for further details.

MIDWEST STEEL
Portage, Indiana

WEIRTON STEEL
Weirton, West Virginia

Divisions of
NATIONAL STEEL CORPORATION

CIRCLE 22 ON READER SERVICE CARD

TEST YOUR ELASTIC STOP® nut KNOW-HOW WITH THIS 60-SECOND QUIZ

1. To provide controlled interference (locking torque) with bolt threads, the nylon locking insert of an Elastic Stop nut has an I. D. that is
a. ☐ *undersized* *b.* ☐ *same size*
in relation to major diameter of standard bolts.

2. As bolt threads enter the nylon locking collar they
a. ☐ *cut* *b.* ☐ *impress*
perfect mating threads and bring bolt and nut thread surfaces into firm metal-to-metal contact.

3. An Elastic Stop nut
a. ☐ *increases* *b.* *diminishes* *c.* ☐ *eliminates*
wear producing axial play between bolt and nut.

4. Upon removal from the bolt, the nylon collar of an Elastic Stop nut
a. ☐ *retains its thread impressions.* *b.* ☐ *tends to resume its original shape.*

5. A nylon insert Elastic Stop nut can be re-used without losing its locking torque
a. ☐ *10 times* *b.* ☐ *25 times* *c.* ☐ *over 50 times*

6. An Elastic Stop nut will
a. ☐ *always* *b.* ☐ *sometimes* *c.* ☐ *never*
seize, gall or remove plating from bolt threads.

7. An Elastic Stop nut can be
a. ☐ *more accurately* *b.* ☐ *less accurately*
prestressed than an all-metal nut.

8. Regardless of vibration, impact or stress reversal an Elastic Stop nut will stay put
a. ☐ *anywhere on the bolt.* *b.* ☐ *only when torqued against the work.*

9. Fuels, lubricants, moisture
a. ☐ *can* *b.* ☐ *cannot*
seep past the chemically inert locking collar to cause corrosion of internal bolt-nut threads.

10. The single-unit Elastic Stop nut costs approximately
a. ☐ *more* *b.* ☐ *the same* *c.* ☐ *less*
to install than a castellated nut and cotter pin, or a double nut.

Check Your Score

1 a. 2 b. 3 c. 4 b. 5 c. 6 c. 7 a. 8 a. 9 b. 10 c.

Write Dept. S62-1145 for Elastic Stop nut Bulletin describing hundreds of Elastic Stop nut hex shapes and sizes—from 0-80 to 4"—in carbon and stainless steels, brass, aluminum and other alloys, in all standard finishes.

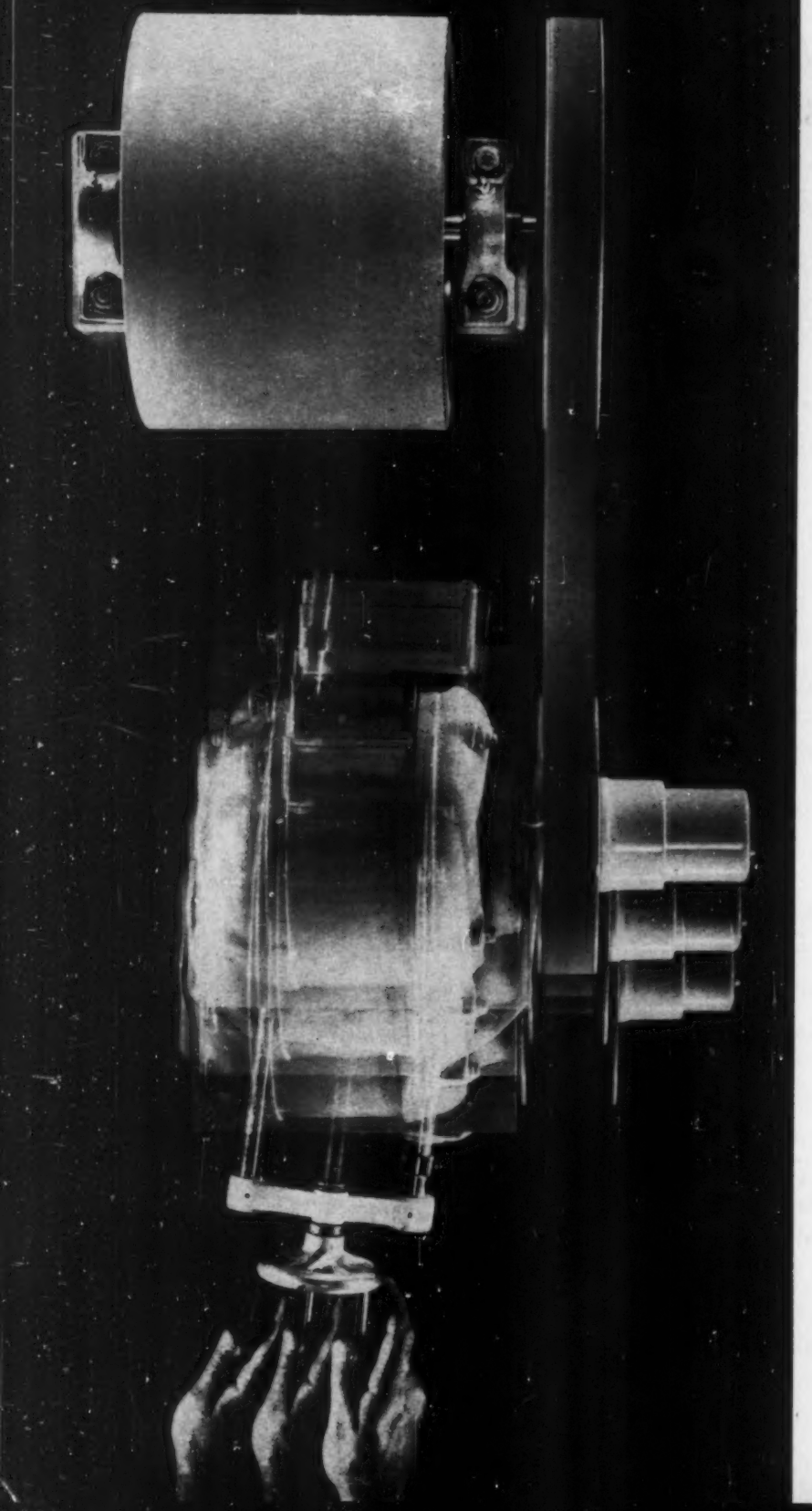
ESNA®

ELASTIC STOP NUT CORPORATION OF AMERICA

2330 Vauxhall Road, Union, New Jersey

for the ring of reliability

SPEED IT UP...SLOW IT DOWN...



ONLY THIS DRIVE IS SIMPLEST, MOST ECONOMICAL ...TROUBLE-FREE

The drum at the top—it could represent one of your machines—changes speed smoothly with each turn of the handwheel. Of at least four ways to do this with simple V-belt drives, only the Worthington Variable Speed Motor Pulley system is so simple, so trouble-free.*

What is so different? In any V-belt system you must, of course, keep the belt perfectly aligned or increased wear will result. The Worthington drive does this perfectly . . . automatically. The illustration shows how.

See how the motor and motor pulley are mounted on Worthington's exclusive Angle-Matic base. The motor travel is at a slight (but precise) angle to the line of the belt. So, as the handwheel is turned, the inner motor pulley flange moves laterally in exact synchronization to its widening gap. And the spring-loaded outer flange stays in perfect alignment, too.

Now compare the Worthington Angle-Matic base and the simple, single-moving-flange Motor Pulley with other systems. One requires a highly complex dual-moving flange pulley. Another requires two adjustable sheaves. A third uses a substitute for the true V-groove companion sheave. None are so simple or trouble-free.

This is just one example of how Worthington gives you more value in variable speed drives. This Motor Pulley produces speed ratios up to 3:1 and is available for ⅓th to 15 hp. For more information, please contact your nearest Worthington distributor listed in the Yellow Pages. Or write Worthington Corporation, Section 79-36, Oil City, Pa.

PRODUCTS THAT WORK
FOR YOUR PROFIT

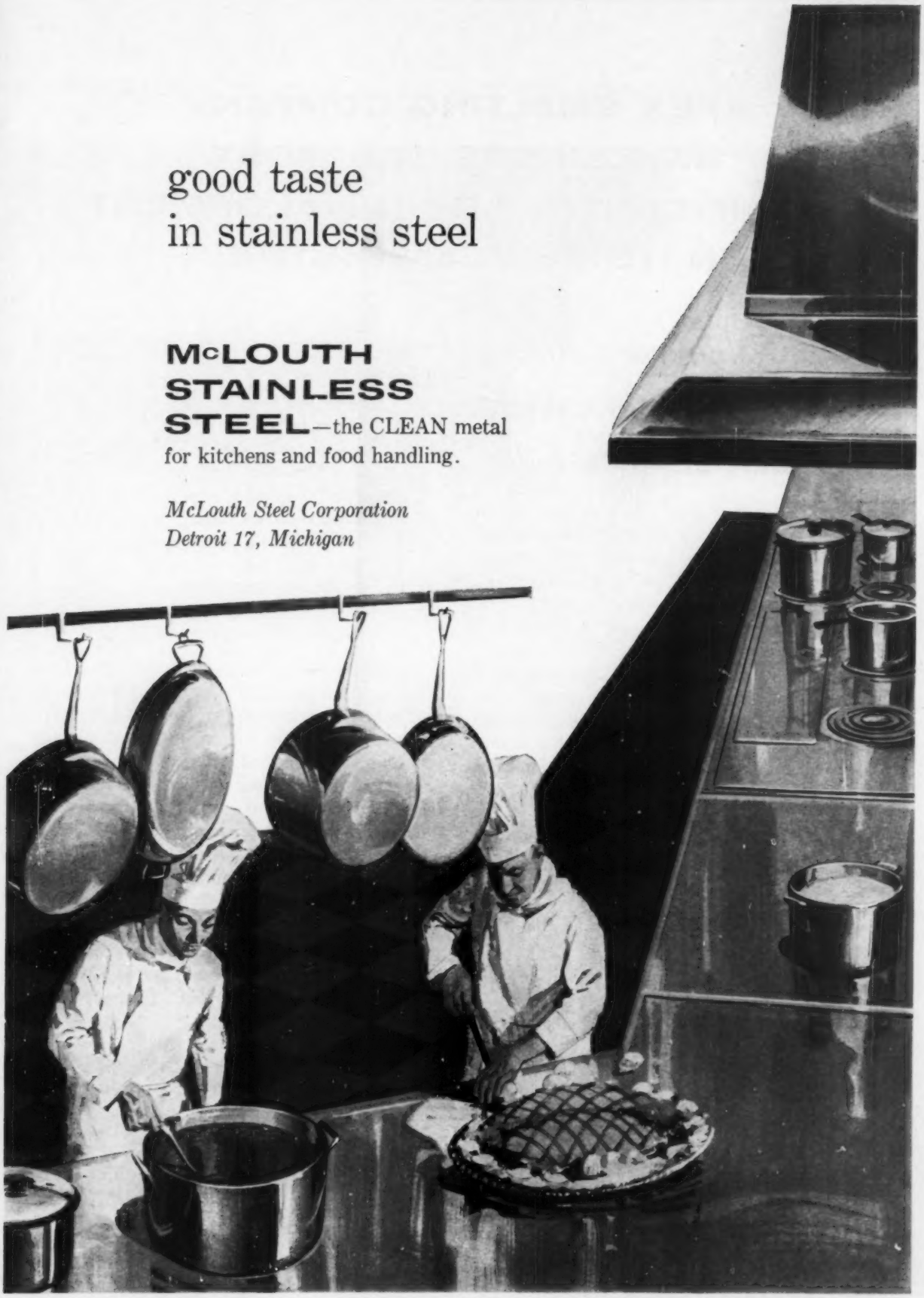
WORTHINGTON

*How does it work? As the handwheel turns one way, it pulls the motor back from the drum; the belt forces itself deeper in the motor pulley; the flanges move apart, effectively reducing the pulley diameter. Because the motor turns at constant speed, the smaller pulley diameter causes the drum to slow down. Turn the handle the other way, the drum speeds up. Up to 3:1 speed change is made by this Worthington drive.

good taste in stainless steel

McLOUTH STAINLESS STEEL—the CLEAN metal for kitchens and food handling.

McLouth Steel Corporation
Detroit 17, Michigan



←CIRCLE 24 ON READER SERVICE CARD

CIRCLE 25 ON READER SERVICE CARD

APEX SMELTING COMPANY ANNOUNCES THE MOST SIGNIFICANT ALLOY DEVELOPMENT IN ITS 38-YEAR HISTORY

Aluminum Alloys for die casters now part of Allcast line

For years Allcast 70, developed by Apex laboratories, has been the alloy that sand and permanent mold foundries prefer for their difficult jobs to achieve consistently high fluidity, absence of shrinkage, pressure tightness and a consequent high yield with a minimum of rejected castings.

Recognizing that die casters, too, had need of an alloy possessing not only these characteristics, but also offering minimum sludging and soldering, Apex's technical staff experimented with a variety of alloy heats and additives. Yet, after hundreds of tests, the elusive goal of consistent results had still not been achieved.

Then, early this year, Apex's technical staff was elated to hit upon new refining and alloying procedures that held promise of yielding the desired results.

Would the resulting alloy stand up under "tough job" conditions in the field? To get the answer, Apex enlisted the help of a number of its die casting customers and asked them to put the new alloy to the test. With shipment after shipment, on a consistent basis, these customers reported obtaining benefits such as these:

Increased fluidity
Minimum sludge formation
Less porosity and cold flows
Less lubricant required
Less tendency to solder
More shots per hour
Lower casting temperatures
Extended die life
Brighter surface finish
Better machinability
Greater pressure tightness

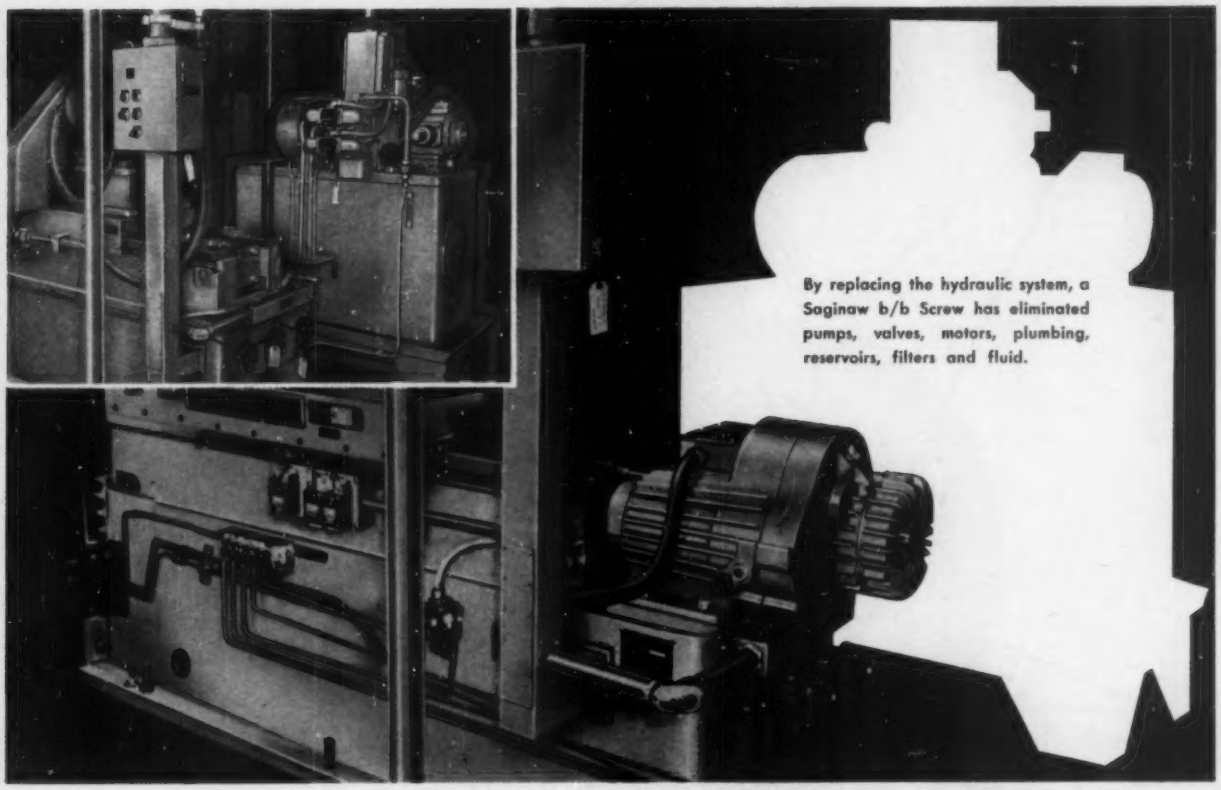
Though the new alloy appeared assured of acceptance, another big obstacle to practical adoption still remained—the substantially higher production costs of the new refining and alloying procedures. It remained for the Apex executive committee to resolve this problem by authorizing the expenditure of up to a million dollars for plant modernization and new equipment whose greater efficiency is expected to offset the increased costs. At the same time, the executive committee authorized immediate adoption of the new procedures, with Apex absorbing the higher costs.

Apex Allcast aluminum die cast alloys, prepared in conformance with standard or custom specifications, are now available at Apex's Chicago, Cleveland and Los Angeles plants.

APEX SMELTING COMPANY

Chicago 12 • Cleveland 5 • Long Beach 10, California
Springfield, Oregon (National Metallurgical Corp.)

EFFICIENCY in a world of motion



By replacing the hydraulic system, a Saginaw b/b Screw has eliminated pumps, valves, motors, plumbing, reservoirs, filters and fluid.

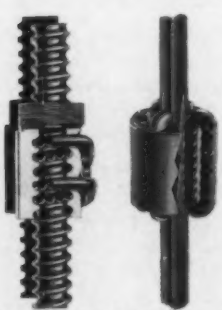
b/b screw leaves room to spare

THE SPACE-SAVING Saginaw Ball Bearing Feed Screw on this automatic transfer machine is far more efficient, economical and maintenance-free than the hydraulic system it replaced. *High Efficiency* — more than 90% — is the secret of its superior performance.

Uniform feed despite load changes caused by hard or soft spots or interrupted cuts frequently doubles cutting tool life! The need for power sources, gears and controls is reduced . . . operating costs are less . . . housekeeping and maintenance are minimized.

Which of these Saginaw b/b Screw advantages are important to you?

HIGH EFFICIENCY exceeding 90% of input;
LIFE predictable within 10%;
STEPLESS CONTROL over the entire length of the stroke;
HIGH REPEATABILITY of any position;
PRECISE POSITIONING — no stick-slip or expansion due to friction induced heat;
EASE OF SYNCHRONIZING multiple units;
SMALLER COMPONENTS in the power source and drive transmission, and
RELIABILITY under varied operating conditions.



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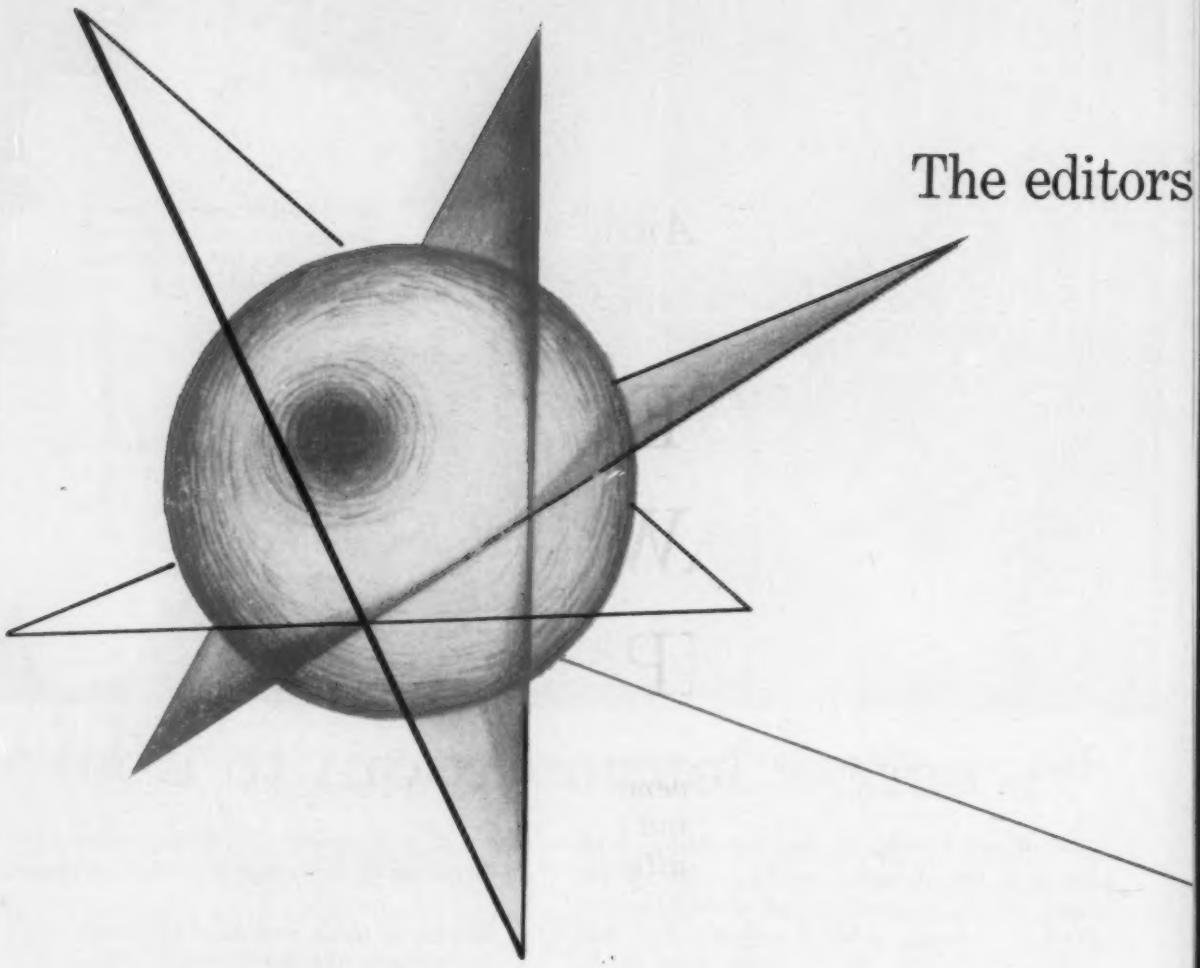
Saginaw ball/bearing SCREWS and SPLINES

SAGINAW STEERING GEAR DIVISION • GENERAL MOTORS CORPORATION • SAGINAW, MICHIGAN



The editors

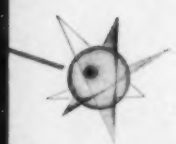
..... of PRODUCT ENGINEERING

Announce the

THIRD ANNUAL

MASTER DESIGN AWARDS COMPETITION

for Achievement in Product Design and Development in the United States during 1961



Here is your opportunity to secure top industry recognition for products developed by your company during 1961. Awards are made *on an individual basis* to the engineers directly responsible for the design of these products. Although your company also receives recognition, the primary purpose is to recognize and reward *individual* design achievement.

SEND FOR YOUR ENTRY FORM TODAY. Fill out and mail the coupon at right and you will receive copies of the Official Entry Form outlining the simple procedures for entering the Awards Competition. Or, if you prefer, write "Awards Folder" on the Reader Service Card.

All entries must be received by PRODUCT ENGINEERING editors not later than January 15, 1962. Winning entries will be featured in the April 16, 1962, issue of PRODUCT ENGINEERING. Awards will be presented during the Design Engineering Show in Chicago, April 30-May 4, 1962.

Editors
PRODUCT ENGINEERING
330 West 42nd St., New York 36, N.Y.

Please send me Official Entry Forms for the 1962 Master Design Awards Competition.

Name_____

Company_____

Street & No._____

City & State_____

GOODYEAR

NEWS! ONLY V-BELTS BY GOODYEAR

to give you sets matched in length to pull together

What's more, Green Seal V-Belts give you—

True dimensional stability for the life of the belt—built in through the use of shrink- and stretch-resistant 3-T Process Cord or airplane-type steel cable.

Mildew-inhibited construction for protection in damp operating conditions.

Widest selection from the most complete V-belt line anywhere.

Ready availability from distributor stocks in every part of the country.

Technical assistance whenever it's needed from a qualified expert, the G.T.M.—Goodyear Technical Man.

For the best buy in V-belts call your Goodyear Distributor. Or write Goodyear, Industrial Products Division, Akron 16, Ohio.

Lots of good things come from GOOD

GREEN ✿ SEAL ARE CODED TO 1/32"...

perfectly for longer, more trouble-free service

LENGTH-CODING GREEN SEAL V-BELTS TO 1/32"—NOT JUST 1/10", LIKE MOST BELTS—takes this ultra-precision machine. Only Goodyear has this type equipment, which is set by means of fine tolerance steel templates to insure accuracy. Machine readings are in the actual code numbers used to eliminate errors.

Green Seal—T. M. The Goodyear Tire & Rubber Company, Akron, Ohio

YEAR INDUSTRIAL PRODUCTS

CIRCLE 31 ON READER SERVICE CARD

More OEM's than ever before are swinging to FORD POWER ...because

1 ALL FORD INDUSTRIAL ENGINES ARE COMPACT OHV DESIGN

2 FORD INDUSTRIAL ENGINES DELIVER MORE HORSEPOWER

3 FORD INDUSTRIAL ENGINE SERVICE IS AVAILABLE EVERYWHERE

These are just a *few* of the many reasons original equipment manufacturers from coast to coast are specifying Ford Industrial Engines.

Only Ford offers a *full line* of modern, overhead-valve-design engines. They're compact and modern, delivering *more horsepower per pound of engine weight than ever before possible.* For OEM design engineers, this means greater freedom of equipment design plus important weight savings!

For *true* economy, Ford's short stroke design can't be matched . . . it minimizes friction and delivers more *usable* power from every drop of fuel! And overhead valves permit faster, easier servicing. Costly downtime is further pared for your customers by the immediate availability of parts and service. *All* the more commonly purchased replacement parts are stocked by your nearest Ford Dealer.

Ford Industrial Engines range from 134 to 534 cubic inches, including modern diesels. Most engines are available as foot- or skid-mounted power units. For dependable power that can be easily matched to your original equipment requirements . . . specify Ford Industrial Engines!

Ford
INDUSTRIAL ENGINES
AND POWER UNITS

YOUR JOB IS WELL-POWERED WHEN IT'S FORD-POWERED!

INDUSTRIAL ENGINE DEPARTMENT, FORD DIVISION, FORD MOTOR CO., P.O. BOX 135, DEARBORN, MICH.

West of Rockies write to:
→ FORD INDUSTRIAL ENGINE DEPT., P.O. BOX 6787, LOS ANGELES 22, CALIF.
→ FORD INDUSTRIAL ENGINE DEPT., P.O. BOX 1666, RICHMOND, CALIF.

CIRCLE 33 ON READER SERVICE CARD→

How a Design Engineer took the fatigue cracks out of a high-stress turnpost

Designed originally as a weldment, this turnpost for a hydraulic loader was failing too often in the field—particularly when severely overloaded during sub-zero winter logging operations.

Analysis of failures indicated abnormal buildup of loads at stress concentration points in the heat-affected area of the weldment. Fatigue cracks also appeared in the top plate shoulder because of unyielding stiffness at the weld line. Undesirable permanent set in the weldment developed below the shoulder prior to failure.

The turnpost was converted to a forging without the necessity for redesign of any other assembly component—with a cost reduction of $7.72 per turnpost. The log-loader manufacturer reports . . . "we have received no complaints about turnpost failures since changing to a forged part."

Read details of this forging application on the following pages.

FORGED

FOR RELIABILITY

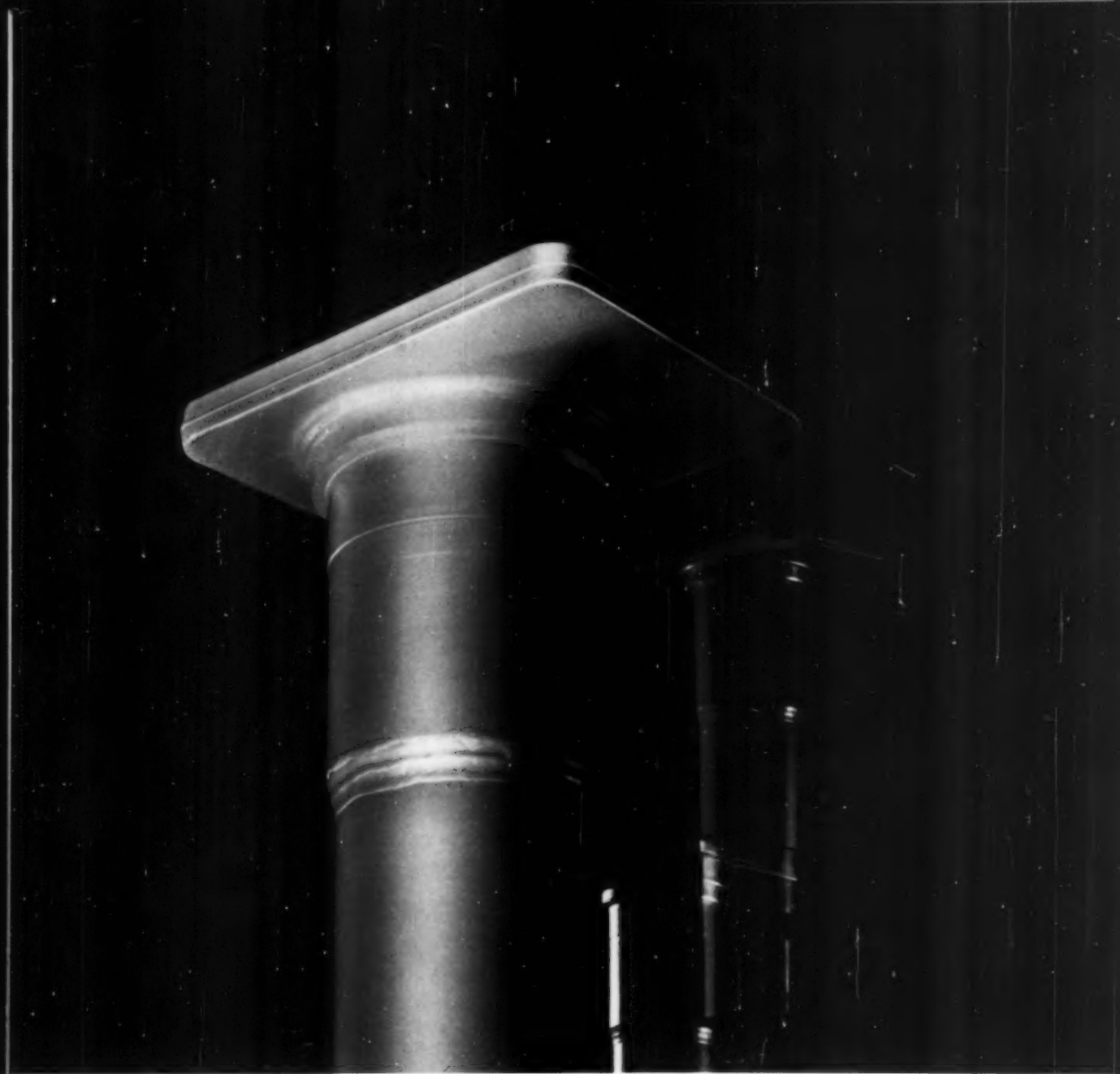
Specifically...

The combination of improved properties provided by forgings eliminated failure from overloads, mechanical shock, and sudden stress reversals on unloading.

The unique long-fiber grain structure of the forged part—a myriad of microscopic "reinforcing bars"—was oriented at right angles to the severest stresses, providing maximum strength at critical points.

High strength of the forged turnpost provided an estimated 45 per cent increase in fatigue resistance at points of maximum stress concentration with a 25 per cent reduction in average wall thickness. Excessive stiffness and rigidity associated with the former massive column design was eliminated.

Because forgings are made from the best grades of rolled bar stock and never pass through the liquid state during production, they contain no voids, gas bubbles, unwanted segregates, or dangerous inclusions. Such faults can impair value and hike end costs, particularly where machining is required.



In summary, by converting to a forging the designer put to work this particular combination of forging properties:

1. High modulus of elasticity
2. Maximum impact strength
3. Low mechanical hysteresis
4. High fatigue resistance
5. Stress-oriented grain structure
6. Solid, void-free metal

CASE STUDY REPORT

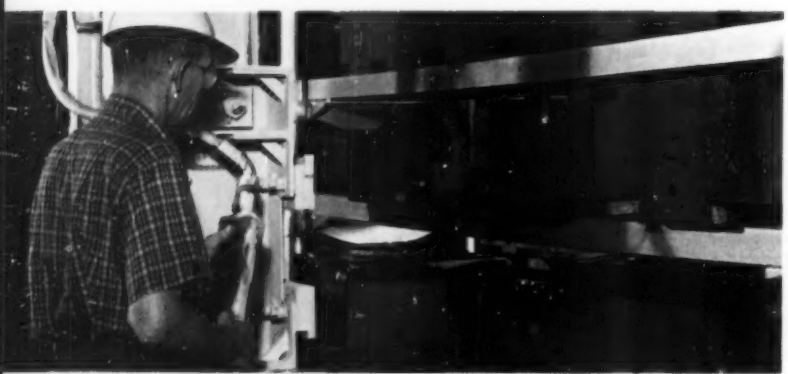
Learn how the designer licked this turnpost design problem. Write for the CASE STUDY REPORT complete with drawings, photographs and full technical information—available without charge on request. Mail your request to Drop Forging Association • Dept. PE-1 • 55 Public Square • Cleveland 13, Ohio.

When it's a vital part, design it to be FORGED

Modern forging equipment and technology keep forging plants modern in production, competitive in price.

Even greater uniformity of parts is achieved by this fully-automatic forging line now in operation at a modern forging plant. Automatic cycling and transfer of forging stock speeds production, keeps parts costs down, improves quality and tolerances of forgings, benefits forgings users.

Careful quality control and uniformity of finished forgings begins with a preliminary visual inspection which is followed by precision dimensional checking.



This mechanized "stack-rack" manipulator in a modern forge shop helps store precise forging dies weighing hundreds of pounds in easy-to-reach racks, eliminates die damage, speeds delivery of dies to the forging-equipment area.

THE FOLLOWING COMPANIES OF THE FORGING INDUSTRY HAVE SPONSORED THIS INFORMATIVE SERIES OF CASE STUDIES:

CALIFORNIA
California Drop Forge Company • Los Angeles, Calif.
Kortick Manufacturing Company • San Francisco, Calif.

CONNECTICUT
The Billings and Spencer Company • Hartford, Conn.
Wilcox-Crittenden Div., N. & J. Mfg. Co.
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ILLINOIS
AmForge, Div. American Brake Shoe Co. • Chicago, Ill.
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Forgings & Stampings, Inc. • Rockford, Ill.
Kropp Forge Company • Chicago, Ill.
Modern Drop Forge Co. • Blue Island, Ill.
Pettibone Mulliken Corporation • Chicago, Ill.
Rockford Drop Forge Co. • Rockford, Ill.
Standard Forgings Corporation • Chicago, Ill.
Taylor Forge & Pipe Works • Chicago, Ill.

INDIANA
Broderick Co., Div. of Harsco Corp. • Muncie, Ind.
Indianapolis Drop Forging Co., Inc. • Indianapolis, Ind.
Portland Forge, Incorporated • Portland, Ind.

MAINE
Thos. Laughlin Div., Amer. Hoist & Drk. Co.
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Cape Ann Tool Company • Pigeon Cove, Mass.
H. E. Holbrook Drop Forge, Inc. • Worcester, Mass.
Porter Forge & Furnace Inc. • Somerville, Mass.
Storms Drop Forging Company • Springfield, Mass.
Wyman-Gordon Company • Worcester, Mass.

MICHIGAN
Buchanan Steel Products Corporation • Buchanan, Mich.
Federal Drop Forge Company • Lansing, Mich.
Huron Forge & Machine Company • Detroit, Mich.
Michigan Forging Company • Dearborn, Mich.
Rockwell-Standard Corp., Forge Div. • Detroit, Mich.

NEW JERSEY
Garden State Forge Company • South Plainfield, N. J.

NEW YORK
The Brewer-Titchener Corporation • Cortland, N. Y.
The E. D. Clapp Mfg. Co., Inc. • Auburn, N. Y.
Endicott Forging & Mfg. Co., Inc. • Endicott, N. Y.
Merrill Brothers • Maspeth, N. Y.

OHIO
The Alliance Drop Forging Company • Alliance, O.
The Ashtabula Bow Socket Company • Ashtabula, O.
The Champion Rivet Company • Cleveland, O.
Columbus Bolt & Forging Co. • Columbus, O.
Eaton Manufacturing Co., Marion Div. • Marion, O.
The Harris-Thomas Drop Forge Co. • Dayton, O.
Poor & Co., Canton Forge & Axle Works • Canton, O.
H. K. Porter Co., Forge & Fittings Div. • Cleveland, O.
The Steel Improvement & Forge Co. • Cleveland, O.
Transue & Williams Steel Forging Corp. • Alliance, O.

PENNSYLVANIA
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Keystone Forging Co. • Northumberland, Pa.
The Lakeview Forge Company • Erie, Pa.
Pennsylvania Forge Company • Philadelphia, Pa.
Phoenix Mfg. Co., Div. Union Tank Co. • Catasauqua, Pa.
Pittsburgh Forgings Company • Coraopolis, Pa.
Wilcox Forging Corporation • Mechanicsburg, Pa.

RHODE ISLAND
Rhode Island Tool Company • Providence, R. I.

TEXAS
W. "Pat" Crow, Inc. • Fort Worth, Tex.
LeBus Mfg. Co., Amer. Hoist & Drk. Co. • Longview, Tex.
Trinity Forge, Inc. • Hurst, Tex.

WISCONSIN
Interstate Drop Forge Co. • Milwaukee, Wis.
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Milwaukee Forge & Machine Company • Milwaukee, Wis.
Unit Drop Forge, Div. Eaton Mfg. Co. • Milwaukee, Wis.
Walker Forge, Inc. • Racine, Wis.

CANADA
Canadian Warren Pink Limited • St. Catharines, Ontario
Dominion Forge Co., Div. Canman Ind. Ltd.
Windsor, Ontario

When it's a vital part, design it to be **FORGED**

DEVELOPMENTS TO WATCH

New instruments to measure time and frequency; a strain gage for use at temperatures to 1500 F; and a generalized electrical machine that's a sort of granddaddy of today's generators, transformers and synchros and the forerunner of those to come, highlight the R & D news. There are new miniature motors, too, and some exciting developments in the high-temperature field.

The generalized electrical machine was developed in England to simplify teaching of basic electrical theory but it is expected to find many R & D applications as well.

As its developers point out, most electrical machines have a stationary member and a rotating member separated by an air gap; and the members carry windings coupled by the magnetic flux. Such a machine, with windings on both axes on both stationary and rotating members, may be called a primitive machine. In actual machines some of these windings may be non-existent; or there may be several additional windings on one or both axes.

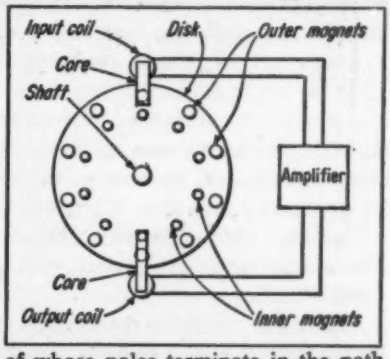
By varying the connections of the windings of this primitive machine, then, and providing for excitation by ac or dc, it is possible to simulate almost every type of machine that is now in use.

The generalized machine, as developed by the Motor and Control Div of AEI Ltd and researchers at Queen Mary College (U of London), consists of stator, commutator link board, rotor, hand-operated brush gear, and motor-operated brush gear.

The machine is coupled to a dc shunt machine which drives and loads it, and the complete machine set also includes a torquemeter oscillator, rotor tachometer-generator, torquemeter coupling, brush gear drive motor, and brush gear tachometer generator. A number of connecting devices and other novel design features are provided to permit demonstration of various types of machines.

New miniature motors, one unusually simple in design, have been developed by Hamilton Watch Co.

The simplified motor is an electric impulse unit that's aimed at applications where rotational speed is not critical. This makes it possible to eliminate such speed-control devices as vibrators; and to produce an unusually low-cost motor, and, because it may be stalled without drawing excessive power or damaging its windings, it can be operated by battery power, and should serve well in such applications as winding watch springs.



It consists of a nonmagnetic disk, carrying two rings of small, cylindrical permanent magnets (see diagram). Above and below the disk are C-shaped cores, one of whose poles terminate in the path of movement of the outer circle, and one in the path of the inner circle of magnets. The first core is connected to the input of an amplifier; the second to its output. As the outer ring of magnets passes between the poles of its core, impulses are sent to the amplifier, producing surges of power which repulse the adjacent magnet on the inner circle, thus driving the disk. This one is not yet commercial; but another new motor soon will be.

The other new motor, just ⅜-in. dia and ½-in. long, is designed for a continuous duty cycle at 1.5 v, 40 mw input, 2.2 mw output at 3300 rpm, with a guaranteed life in excess of 1000 hr.

For time-and-frequency measurement, a four-way unit that combines a digital voltmeter with a clock pulse source, a time interval meter, and a frequency meter,

will soon be available. Designed by Southern Instruments Ltd, Camberley, Surrey, England, it will be packaged in a portable case and will feature large, easy-to-read digital displays and a simple function-and-range-selector system.

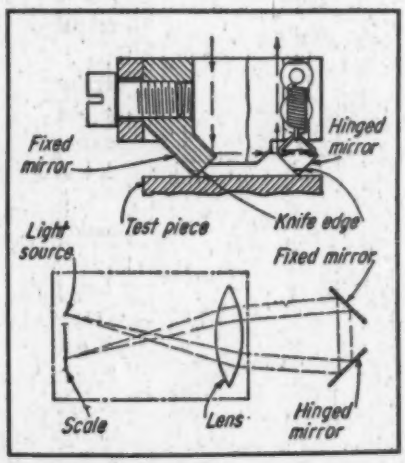
The voltmeter-counter will measure from 1 mv to 500 v; and cover the frequency range from 0.1 cps to 120 kcps, with a count period of 0.1, 1.0, or 10 sec. Time intervals can range from 1 millisec to 27.7 hr, and the crystal-controlled clock will deliver pulses of 0.1, 1, and 10 millisec; 0.1, 1 and 10 sec. The instrument should be available commercially by the end of the year.

If you want to generate sine waves or simulate machine functions, without fancy electronic wave-shaping circuits and specially shaped and wound potentiometers, Advance Components Ltd, Hainault, Essex, England has the answer—a new optical-mechanical function generator.

Instead of a conventional oscillator circuit, the new unit has an unusual system in which transparent rotating disks carry the polar coordinates of the wave shapes to be reproduced. The disks are driven by a servomotor and scanned by a narrow light beam.

By varying the output frequency (from 0.005 to 50 cps or more) and changing the direction of rotation of the disks, almost any wave shape can be generated, providing that its functions are single-valued and repetitive. A built-in oscilloscope with a 1-in. dia tube makes it possible to monitor the wave forms and output voltage level. The unit is about 20 by 13 by 15 in.; weight, 80 lb.

Measuring strain at high temperatures calls for materials that can stand the gaff; and Westinghouse engineers think they have the answer in a hard, heat-resistant alloy iron that will maintain a knife edge at temperatures from 1000 to 1500 F. They're using it for the mirrors and knife edges of a new elevated temperature extensometer. It's an optical strain gage that is placed on the test piece so the two knife edges contact the piece as shown in the upper diagram. Then, as the test piece is heated and elongates, the distance between the knife edges increases and the hinged mirror pivots about its upper edge changing the angle of the reflecting surface. This redirects the light from the auto-collimeter lens (lower sketch), and the change, as shown on the scale, indicates the amount of elongation. In compression, the mirror tilts in the opposite direction, giving a similar reading.



The alloy used for both fixed and hinged mirrors is an iron containing 16% aluminum—1% zirconium, 0.025% boron; and it is surfaced by a platinum reflective coating, also selected for its ability to maintain its properties at high temperature.

• • • •

When it comes to materials for high-temperature use, there are new ceramics, metals, papers, and flame-retardants ready to go to work.

Fire-retardant resins are coming from several new sources:

Mol-Rez Div, American Petrochemical Corp, is introducing a new 2-component **urethane system** (polyether-based) which, it says, produces a snow-white, fire-

retardant foam at a cost of less than 80¢/lb. The components can be mixed at room temperature, and used for air conditioner, water heating, and sandwich panel insulation.

At the same time, AviSun is readying a fire-retardant grade of its new **modified polypropylene** resin (*PE—Sep* 4, *p* 12), claimed to offer unusual rigidity and resistance to heat distortion, and low electrical loss. It's also surprisingly inexpensive—the developmental price for the modified material is less than 40¢/lb.

There's a medium-impact fiberglass-reinforced polyester featuring flame retardance, too, for circuit breaker housings, and similar parts.

Technical information on the *Oleform* modified polypropylenes (regular and flame-retardant types) may be obtained from J. C. Warren, Polymer Sales, AviSun Corp, 1345 Chestnut St, Philadelphia 7; on the Mol-Rez materials from R. C. Kudner, Director of Research & Development, 3134 California St, NE, Minneapolis 18; and on the polyester from Glastic Corp, Cleveland 21.

A noble sandwich is being readied by Englehard Industries for crucibles, thermocouple sheaths, and other applications involving extreme heat and corrosion.

It's a sandwich which combines two layers of wrought platinum with a central powdered metal core. The layers may all be the same composition, or may be of different alloys. Silver, copper, or nickel may be used, too.

The advantage: the powder core prevents transfer of constituents from the melt (molten glass, for instance) through the platinum and prolongs life of the platinum equipment. (When standard material is used, this transfer, which occurs along grain boundaries, may constitute a serious problem.)

Englehard calls the material "Trilay," plans first commercial production in a 3-layer, all-platinum composition with a thickness ratio of 2:1:2.

A new family of alloys that looks unusually good for high-temperature applications is the columbium-vanadium group. Dr David Schlain of Bureau of Mines College Park Research Center says at least one member of the columbium-vanadium system shows "exceptional resistance to corrosion in acid environments at high temperatures."

Westinghouse, too, has been working on this alloy system. Its research lab has quaternary (Cb-V-Mo-Zr and Cb-W-V-Zr) as well as binary alloys in pilot production; believes they'll be suitable for use at operating temperatures to 3000 F. A 96% Cb—4% V alloy is now ready for evaluation, and others will soon be.

An inert, high-melting compound that may prove suitable as a container for liquid aluminum, gallium, and other reactive metals is getting new attention from Bureau of Mines' Thermodynamics Lab (Berkeley). The compound: **aluminum nitride.** A. D. Mah of the Bureau says the material resists decomposition at least to 4000 F. Bureau researchers have been gathering data on heat capacity over the temperature range —367 F to 77 F, entropy, and other thermodynamic characteristics, and have prepared an 8-page report (RI 5716) tabulating the results. Copies may be obtained free of charge from the Bureau Publications Distribution Section, 4800 Forbes Ave, Pittsburgh 13, Penna.

Stronger and more heat-resistant tapes and papers, for thermal and electrical insulation, are coming.

Just recently, C H Dexter & Sons announced commercial production of a new quartz fiber material for heatshield laminates and similar applications. It stands arc heat—3000 F—at least on an intermittent basis, and is relatively inexpensive (15¢ to 40¢/sq ft).

There's a new heat-resistant electrical insulating tape on its way, too, based on a new organic-inorganic (phosphonitrilic) polymer. The tape is made by impregnating a polyester resin mat with the new resin, and is designed to serve as armor insulation (to protect silicone wrappings, for instance) on electric motors and in

similar applications; and will stand temperatures of 300 F or more on a continuous basis. New Jersey Wood Finishing Co will produce it commercially.

Ceramic and metal-ceramic bearings are making progress, too, with several compositions showing promise for the 1000- to 1500-F range.

A cooperative study under sponsorship of Wright Air Development Div, has given a big boost to nickel titanium carbide as a bearing material. An ASME report on the study says nickel titanium carbide, will stand a 50 lb thrust load at 8000 rpm for at least 8 hr at 1500 F without significant wear or damage. Dry lubrication will improve performance. But even without it, the titanium carbide cermet proved superior in sliding friction and wear tests.

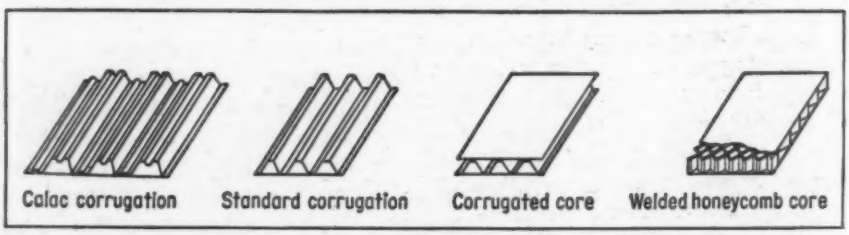
A new approach to bearing design for high-temperature operation—exotic, but nonetheless interesting—was suggested by W. T. Snyder of the State University of New York at a recent ASME-ASLE meeting. The idea: improve load-carrying ability by operating the bearing in a conductive (liquid metal) medium, with an applied magnetc field to control "lubricant" distribution.

The system has other advantages as well: The high thermal conductivity of liquid metals means that heat generated by viscous action at high speed is readily conducted away from the source of generation, thus resulting in a tendency toward uniformity of temperature and viscosity within the lubricant film.

• • • •

Structural engineers are exploring new materials—and studying optimum design of paneling and vibration-damping systems.

Where high strength-weight ratios are required—as they are in many types of mobile equipment—Lockheed engineers are now recommending the CALAC type of corrugation. This, as shown in the diagram, is a standard corrugation with an extra dimple in the top. Tests of thin-gage sandwich structures made this way get a high produceability rating (they are quite readily assembled by spot



welding), and offer a good many other advantages, not the least of which is low cost. M. B. Childers and V. B. Koriagin of Lockheed told a recent SAE meeting, the CALAC structures are considerably less expensive to produce than honeycomb sandwiches, though they cost more than standard corrugations; and CALAC panels have a weight-strength ratio lower than any of the other types sketched here.

New vibration damping materials for sheet metal are being created at Farbwerke Hoechst (West Germany) by taking advantage of the special properties of amorphous high polymers.

Hermann Oberst of FH told the Acoustical Society that these materials can be adjusted to provide optimum damping at given frequencies in temperature bands of prescribed position and width. The polymers can be mixed or copolymerized, and fillers can be added to obtain almost any desired spectrum of internal energy losses at any specified temperature. **—ARG**

Table speeds calculation of

Strength of threads

When different classes of screw threads are mated calculations become complex. Table gives minimum shear areas avoiding much tedium and chance of error.

RAYMOND C BOUCHER, American Machine & Foundry Co, Stamford, Conn

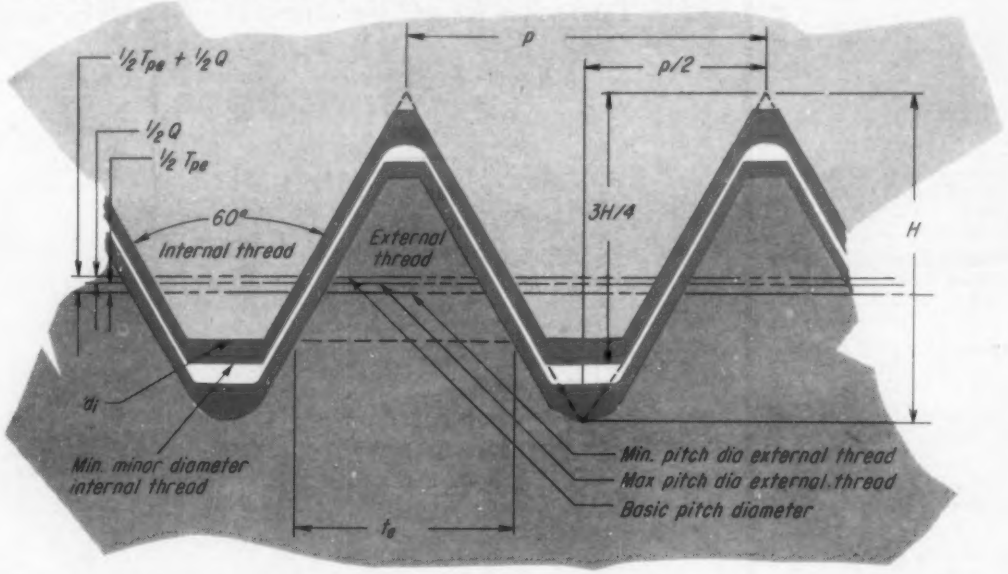
THE MOST laborious part of finding the axial shear or tensile strength of screw thread is calculating the effective area. Formulas are available for finding the precise shear area (see Handbook H28 Part I, National Bureau of Standards, 1957), but with the tabular data given here the effective area can now be determined precisely with minimum computations. This table covers the usual case, where both internal and external threads are of the same class.

Also provided are formulas useful when it is necessary, or even desirable, to use one class of thread for the internal member and a different class for the external member. The formulas derived here will give precise shear area when the various factors in the formulas are adjusted for the minimum material condition of internal and mating external thread.

Here is what to expect after mixing different classes of threads:

• When one thread is mated with another, of a numerically higher class, its shear area will be greater than shown in the applicable table. For example, a class 2A mated with a class

1..Shear areas of an external thread



SYMBOLS

A_e = min area in shear—external thread. (sq in./in. of length)

A_i = min area in shear—internal thread. (sq in./in. of length)

A_t = min tensile stress area—external thread. (sq in.)

D_B = basic major diameter—external thread. (in.)

D_t = min tensile stress diameter—external thread. (in.)

d_e = min major diameter—external thread. (in.)

d_i = max minor diameter—internal thread. (in.)

H = maximum possible height of thread. (in.)

L = length of thread engagement measured axially at pitch diameter. (in.)

n = threads per inch $(1/p)$

p = pitch of thread (in.)

P_e = min strength in shear—external thread in assembly. (lb)

P_i = min strength in shear—internal thread in assembly. (lb)

P_t = tensile strength of externally threaded piece. (lb)

Q = allowance on all diameters of the external thread.

S_e = shear strength of the material of the external thread. (psi)

S_i = shear strength of the material of the internal thread. (psi)

S_t = tensile strength of material. (psi)

t_e = min cross-sectional thickness of the external thread in line with d_i. (in.)

t_i = min cross-sectional thickness of the internal thread in line with d_e. (in.)

T_{pe} = tolerance on the pitch diameter of the external thread. (in.)

T_{pi} = tolerance on the pitch diameter of the internal thread. (in.)

T_{de} = tolerance on the major diameter of the external thread. (in.)

T_{di} = tolerance on the minor diameter of the internal thread. (in.)

3B has a shear area A_e greater than shown; a 2B with a 3A also has a greater shear area A_t.

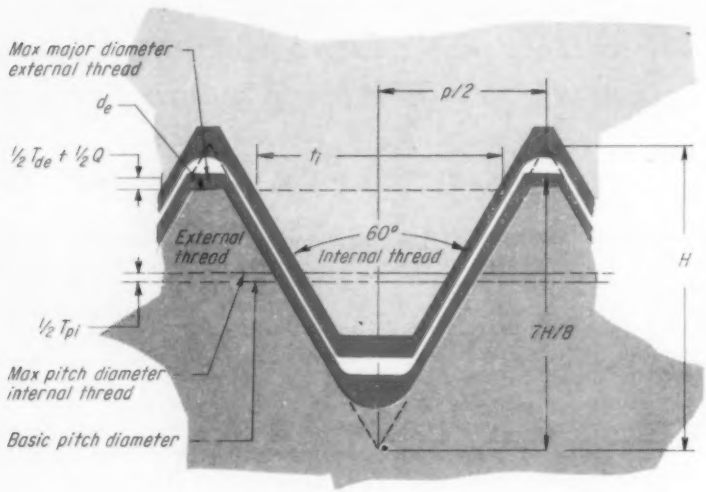
• When one thread is mated with another, of a numerically lower class, its shear area wil be less than shown in the applicable table; eg a class 3B mated with a class 2A has a shear area A_t less than tabled; a 3A with a 2B also has a smaller shear area A_e.

So, for maximum strength it is important to distinguish carefully the applicable shear areas of mated parts with different classifications.

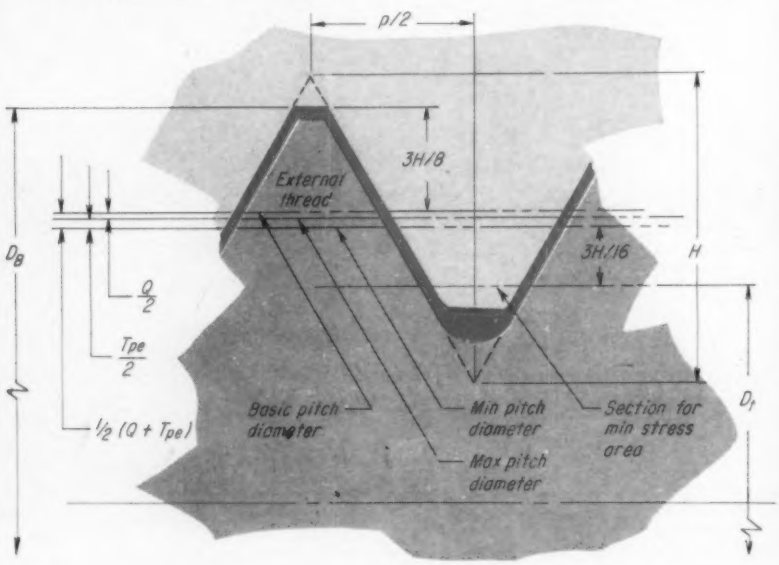
Min shear area—external thread

For longitudinal shear, commonly known as "stripping," the minimum area is determined from the minimum cross-section of the external thread

2..Shear areas of an internal thread



3..Tensile area of an external thread



that is in line with the maximum minor diameter of the mating internal thread. This area (Fig 1) is of importance when the material from which the external thread is fabricated is weaker than that of the mating internal thread. The formula for this area is derived from the basic formula and working from the geometrical relationships shown in Fig 1:

$$A_s = \pi d_s t_s n$$

$$t_s = \left[\frac{3H}{4} - \frac{T_{di} + Q + T_{de}}{2}\right] 2 \tan 30$$

$$H = \frac{p}{2} \cot 30 = \frac{\sqrt{3}}{2n}$$

$$t_s = \frac{3}{4n} - \left[\frac{T_{di} + Q + T_{de}}{\sqrt{3}}\right]$$

$$A_s = d_s[2.3562 - 1.8138n\,(T_{di} + Q + T_{de})] \quad (1)$$

The area A_s in Eq (1) for the various series of external threads is given in the table. The tolerances T_{di}, for thread sizes above 3/8 were taken from Handbook H28; mentioned above; for thread sizes 3/8 and below they were determined by subtracting the minimum minor diameter of the internal thread, as given in H28, from the maximum tap drill diameter. All other

Shear and tensile areas of screw threads

THREAD SIZE	n	SERIES	A_s FOR CLASS: 1A	2A	3A	A_t FOR CLASS: 1A	2A	3A	A_t FOR CLASS: 1B	2B	3B
#0 (0.060)	80	NF	.....	0.0819	0.0890	.....	0.0016	0.0017	.....	0.1057	0.1158
#1 (0.073)	64	NC	.....	0.0878	0.0956	.....	0.0024	0.0025	.....	0.1328	0.1444
	72	NF	.....	0.0939	0.1055	.....	0.0026	0.0027	.....	0.1300	0.1420
#2 (0.086)	56	NC	.....	0.1111	0.1192	.....	0.0034	0.0035	.....	0.1615	0.1736
	64	NF	.....	0.1237	0.1329	.....	0.0037	0.0038	.....	0.1571	0.1706
#3 (0.099)	48	NC	.....	0.1399	0.1490	.....	0.0045	0.0046	.....	0.1909	0.2046
	56	NF	.....	0.1365	0.1476	.....	0.0049	0.0050	.....	0.1862	0.2011
#4 (0.112)	40	NC	.....	0.1524	0.1616	.....	0.0056	0.0057	.....	0.2215	0.2377
	48	NF	.....	0.1485	0.1593	.....	0.0062	0.0063	.....	0.2164	0.2319
#5 (0.125)	40	NC	.....	0.1704	0.1818	.....	0.0074	0.0076	.....	0.2479	0.2635
	44	NF	.....	0.1684	0.1795	.....	0.0078	0.0080	.....	0.2455	0.2613
#6 (0.138)	32	NC	.....	0.2002	0.2097	.....	0.0085	0.0087	.....	0.2807	0.2962
	40	NF	.....	0.2026	0.2144	.....	0.0095	0.0098	.....	0.2740	0.2920
#8 (0.164)	32	NC	.....	0.2242	0.2372	.....	0.0132	0.0136	.....	0.3343	0.3536
	36	NF	.....	0.2494	0.2540	.....	0.0140	0.0143	.....	0.3316	0.3508
#10 (0.190)	24	NC	.....	0.2761	0.2882	.....	0.0166	0.0170	.....	0.4008	0.4197
	32	NF	.....	0.2809	0.2961	.....	0.0190	0.0194	.....	0.3886	0.4107
	24	NC	.....	0.3130	0.3272	.....	0.0229	0.0235	.....	0.4572	0.4735
#12 (0.216)	28	NF	.....	0.3136	0.3306	.....	0.0246	0.0251	.....	0.4493	0.4738
	32	NEF	.....	0.3247	0.3422	.....	0.0259	0.0264	.....	0.4415	0.4664
	20	UNC	0.3663	0.3805	0.3953	0.0298	0.0303	0.0309	0.4738	0.5396	0.5623
1/4	28	UNF	0.3790	0.3978	0.4176	0.0344	0.0349	0.0355	0.4474	0.5213	0.5494
	32	NEF	.....	0.3827	0.4060	.....	0.0364	0.0371	.....	0.5100	0.5418
	18	UNC	0.4761	0.4922	0.5127	0.0496	0.0503	0.0512	0.6036	0.6816	0.7101
5/16	24	UNF	0.4264	0.4725	0.4977	0.0553	0.0560	0.0569	0.5777	0.6627	0.6957
	32	NEF	.....	0.4833	0.5131	.....	0.0607	0.0614	.....	0.6412	0.6806
	16	UNC	0.5869	0.6061	0.6259	0.0737	0.0747	0.0759	0.7378	0.8280	0.8596
3/8	24	UNF	0.6045	0.6323	0.6615	0.0843	0.0853	0.0863	0.6931	0.7973	0.8365
	32	NEF	.....	0.5934	0.6317	.....	0.0909	0.0919	.....	0.7681	0.8152
	14	UNC	0.6521	0.6750	0.7324	0.1015	0.1028	0.1043	0.8774	0.9780	1.0127
7/16	20	UNF	0.6515	0.6801	0.7566	0.1142	0.1154	0.1168	0.8333	0.9470	0.9903
	28	UNEF	.....	0.6965	0.7940	.....	0.1244	0.1257	.....	0.9154	0.9659

table continued, next page

dimensions in Eq (1) were taken from Handbook H28.

Min shear area—internal thread

This area is determined from the minimum cross-section of the internal thread that is in line with the minimum major diameter of the mating external thread (Fig 2). This area is of importance when the internal thread is fabricated from a weaker material than that of the external thread, and the formula for it is derived as follows:

$$A_s = \pi d_s t_s n$$

$$t_s = \left[\frac{7H}{8} - \frac{T_{Ds} + Q + T_{ps}}{2}\right] 2 \tan 30$$

$$H = \frac{\sqrt{3}}{2n}$$

Shear and tensile areas of screw threads ... *continued*

THREAD SIZE	n	SERIES	A_s FOR CLASS: 1A	2A	3A	A_t FOR CLASS: 1A	2A	3A	A_t FOR CLASS: 1B	2B	3B
	12	N	.....	0.7756	0.8452	.....	0.1332	0.1352	.....	1.1151	1.1666
1/2	13	UNC	0.7575	0.7821	0.8569	0.1360	0.1376	0.1395	1.0128	1.1231	1.1634
	20	UNF	0.7670	0.8018	0.8898	0.1546	0.1560	0.1577	0.9508	1.0817	1.1327
	28	UNEF	.....	0.7780	0.8785	.....	0.1665	0.1680	.....	1.0435	1.1034
	12	UNC	0.8624	0.8901	0.9704	0.1749	0.1769	0.1790	1.1514	1.2737	1.3170
9/16	18	UNF	0.8570	0.8956	1.0030	0.1965	0.1980	0.2003	1.0877	1.2299	1.2855
	24	NEF	.....	0.8953	1.0005	.....	0.2098	0.2116	.....	1.1975	1.2606
	11	UNC	0.9717	1.0022	1.0960	0.2177	0.2201	0.2225	1.2953	1.4255	1.4708
5/8	12	N	.....	0.9659	1.1041	.....	0.2264	0.2288	.....	1.4146	1.4650
	18	UNF	0.9580	1.0014	1.1349	0.2485	0.2505	0.2529	1.2078	1.3671	1.4285
	24	NEF	.....	0.9998	1.1300	.....	0.2635	0.2655	.....	1.3299	1.3997
11/16	12	N	.....	1.1145	1.2272	.....	0.2821	0.2848	.....	1.5590	1.6142
	24	NEF	.....	1.1048	1.2361	.....	0.3234	0.3256	.....	1.4647	1.5414
	10	UNC	1.1821	1.2170	1.3415	0.3237	0.3266	0.3300	1.5711	1.7225	1.7775
3/4	12	N	.....	1.2257	1.3643	.....	0.3438	0.3470	.....	1.7001	1.7602
	16	UNF	1.1753	1.2259	1.3750	0.3633	0.3660	0.3689	1.4751	1.6585	1.7285
	20	UNEF	.....	1.2378	1.3774	.....	0.3800	0.3826	.....	1.6302	1.7057
	12	N	.....	1.3378	1.4876	.....	0.4127	0.4153	.....	1.8443	1.9092
13/16	16	UN	.....	1.3390	1.5148	.....	0.4361	0.4394	.....	1.8034	1.9422
	20	UNEF	.....	1.3410	1.4859	.....	0.4514	0.4542	.....	1.7677	1.8494
	9	UNC	1.3963	1.4369	1.5866	0.4481	0.4518	0.4560	1.8559	2.0252	2.0859
	12	N	.....	1.4517	1.6262	.....	0.4859	0.4898	.....	1.9884	2.0582
7/8	14	UNF	1.3868	1.4426	1.6368	0.4973	0.5006	0.5043	1.7548	1.9583	2.0344
	16	UN	.....	1.4484	1.6286	.....	0.5124	0.5159	.....	1.9440	2.0252
	20	UNEF	.....	1.4567	1.6221	.....	0.5289	0.5378	.....	1.9053	1.9931
	12	UN	.....	1.5600	1.7480	.....	0.5660	0.5704	.....	2.1286	2.2051
15/16	16	UN	.....	1.5570	1.7636	.....	0.5946	0.5985	.....	2.0792	2.1661
	20	UNEF	.....	1.5280	1.7251	.....	0.6122	0.6157	.....	2.0325	2.1368
	8	UNC	1.6179	1.6606	1.8200	0.5891	0.5937	0.5987	2.1479	2.3256	2.3989
1	12	UNF	1.6091	1.6676	1.8830	0.6478	0.6520	0.6567	2.0476	2.2616	2.3496
	16	UN	.....	1.6662	1.8754	.....	0.6831	0.6872	.....	2.2197	2.3120
	20	UNEF	.....	1.6686	1.8633	.....	0.7020	0.7057	.....	2.1694	2.2804
	12	UN	.....	1.7855	2.0046	.....	0.7450	0.7498	.....	2.4165	2.5027
1 1/16	16	UN	.....	1.7772	2.0146	.....	0.7777	0.7821	.....	2.3597	2.4578
	18	NEF	.....	1.7586	1.9817	.....	0.7879	0.7930	.....	2.3329	2.4342
	7	UNC	1.8305	1.8774	2.2461	0.7431	0.7488	0.7549	2.4485	2.6480	2.7454
	8	N	.....	1.8908	2.0772	.....	0.7763	0.7823	.....	2.6259	2.7018
1 1/8	12	UNF	1.8212	1.8899	2.1366	0.8381	0.8430	0.8483	2.3012	2.5480	2.6418
	16	UN	.....	1.8864	2.1246	.....	0.8785	0.8831	.....	2.5000	2.6037
	18	NEF	.....	1.8677	2.1219	.....	0.8905	0.8947	.....	2.4714	2.5839

$$t_i = \frac{7}{8n} - \left[\frac{T_{De} + Q + T_{pi}}{\sqrt{3}}\right]$$

$$A_i = \pi d_e[0.875 - 0.57735n\,(T_{De} + Q + T_{pi})] \quad (2)$$

The area A_i in Eq (2) for the various series of internal threads is shown in the table and its factors were determined from the same sources as Eq (1).

Min tensile area—external thread

In a threaded assembly it is preferable to have the external thread fail in tension before either the external or internal threads fail in shear. This means that the threaded length should be such that shear strength of either is greater than tensile strength of the external thread. The formula for minimum tensile stress area (Fig 3) is derived as follows:

Shear and tensile areas of screw threads ... *continued*

THREAD SIZE	n	SERIES	A_s FOR CLASS: 1A	2A	3A	A_t FOR CLASS: 1A	2A	3A	A_t FOR CLASS: 1B	2B	3B
13/16	12	UN	.....	2.0084	2.2572	.....	0.9483	0.9539	.....	2.7017	2.7978
	16	UN	.....	1.9940	2.2624	.....	0.9852	0.9902	.....	2.6368	2.7461
	18	NEF	.....	1.9752	2.2268	.....	0.9976	1.0025	.....	2.6021	2.7247
1 1/4	7	UNC	2.0570	2.1098	2.2963	0.9460	0.9524	0.9595	2.7226	2.9441	3.0214
	8	N	.....	2.1220	2.3340	.....	0.9836	0.9903	.....	2.9186	3.0024
	12	UNF	2.0323	2.1091	2.3898	1.0528	1.0583	1.0645	2.5533	2.8291	2.9357
	16	UN	.....	2.1030	2.3703	.....	1.0982	1.1034	.....	2.7769	2.8918
	18	NEF	.....	2.0843	2.3690	.....	1.1113	1.1165	.....	2.7402	2.8692
15/16	12	UN	.....	2.2336	2.5120	.....	1.1763	1.1824	.....	2.9893	3.0952
	16	UN	.....	2.2138	2.5130	.....	1.2174	1.2229	.....	2.9169	3.0375
	18	NEF	.....	2.1917	2.4720	.....	1.2311	1.2366	.....	2.8783	3.0136
1 3/8	6	UNC	2.2954	2.3478	2.5236	1.1276	1.1351	1.1435	3.0349	3.2662	3.3606
	8	N	.....	2.3492	2.5903	.....	1.2150	1.2229	.....	3.2103	3.3043
	12	UNF	2.2393	2.3273	2.6423	1.2918	1.2981	1.3052	2.8006	3.1059	3.2290
	16	UN	.....	2.3228	2.6191	.....	1.3427	1.3485	.....	3.0570	3.1832
	18	NEF	.....	2.3009	2.6162	.....	1.3571	1.3629	.....	3.0165	3.1581
17/16	12	UN	.....	2.4529	2.7639	.....	1.4284	1.4354	.....	3.2704	3.3894
	16	UN	.....	2.4256	2.7595	.....	1.4737	1.4799	.....	3.1844	3.3247
	18	NEF	.....	2.3901	2.7127	.....	1.4890	1.4951	.....	3.1453	3.3025
1 1/2	6	UNC	2.5272	2.5861	2.7818	1.3749	1.3832	1.3924	3.3136	3.5660	3.6351
	8	N	.....	2.5793	2.8465	.....	1.4713	1.4799	.....	3.5016	3.6059
	12	UNF	2.4480	2.5474	2.8943	1.5555	1.5626	1.5703	3.0523	3.3878	3.5185
	16	UN	.....	2.5343	2.8637	.....	1.6112	1.6178	.....	3.3239	3.4703
	18	NEF	.....	2.5442	2.8586	.....	1.6272	1.4422	.....	3.2830	3.4470
19/16	16	N	.....	2.6447	3.0098	.....	1.7549	1.7617	.....	3.4635	3.6158
	18	NEF	.....	2.6050	2.9574	.....	1.7716	1.7782	.....	3.4208	3.5915
1 5/8	8	N	.....	2.8091	3.1021	.....	1.7521	1.7615	.....	3.7921	3.9071
	12	UN	.....	2.7907	3.1625	.....	1.8532	1.8612	.....	3.7010	3.8350
	16	UN	.....	2.7533	3.1122	.....	1.9048	1.9118	.....	3.6030	3.7613
	18	NEF	.....	2.7134	3.1054	.....	1.9221	1.9290	.....	3.5585	3.7359
1 11/16	16	N	.....	2.8590	3.2553	.....	2.0604	2.0678	.....	3.7376	3.9019
	18	NEF	.....	2.8147	3.1967	.....	2.0785	2.0857	.....	3.6907	3.8694
1 3/4	5	UNC	2.9820	3.0462	3.2432	1.8602	1.8711	1.8830	3.9261	4.1996	4.2962
	8	N	.....	3.0361	3.3598	.....	2,0571	2.0678	.....	4.0335	4.2054
	12	UN	.....	3.0117	3.4147	.....	2.1668	2.1755	.....	3.9804	4.1284
	16	UNEF	.....	2.9675	3.3557	.....	2.2225	2.2302	.....	3.8770	4.0472
1 13/16	16	N	.....	3.0777	3.5052	.....	2.3908	2.3987	.....	4.0142	4.1926
1 7/8	8	N	.....	3.2622	3.6150	.....	2.3866	2.3984	.....	4.3707	4.5057
	12	UN	.....	3.2360	3.6704	.....	2.5053	2.5145	.....	4.2669	4.4252
	16	UN	.....	3.1862	3.6038	.....	2.5651	2.5734	.....	4.1556	4.3379
1 15/16	16	N	.....	3.2910	3.7551	.....	2.7453	2.7541	.....	4.2894	4.4832

table continued, next page

Shear and tensile areas of screw threads ... *continued*

THREAD SIZE	n	SERIES	A_s FOR CLASS: 1A	2A	3A	A_s FOR CLASS: 1A	2A	3A	A_s FOR CLASS: 1B	2B	3B
2	4½	UNC	3.4500	3.5204	3.8133	2.4503	2.4635	2.4784	4.5264	4.8280	4.9320
	8	N	.....	3.4906	3.8697	.....	2.7409	2.7535	.....	4.6619	4.8056
	12	UN	.....	3.4561	3.9260	.....	2.8679	2.8781	.....	4.5491	4.7176
	16	UNEF	.....	3.3993	3.8519	.....	2.9319	2.9410	.....	4.4285	4.6285
2 1/16	16	N	.....	3.5093	4.0050	.....	3.1246	3.1341	.....	4.5677	4.7738
2 1/8	8	N	.....	3.7157	4.1243	.....	3.1193	3.1331	.....	4.9495	5.1052
	12	UN	.....	3.6802	4.1816	.....	3.2554	3.2662	.....	4.8353	5.0142
	16	UN	.....	3.6176	4.0940	.....	3.3236	3.3329	.....	4.7069	4.9192
2 3/16	16	N	.....	3.7277	4.2487	.....	3.5286	3.5382	.....	4.8460	5.0645
2 1/4	4½	UNC	3.9254	4.0072	4.2257	3.1921	3.2076	3.2245	5.0942	5.4355	5.5517
	8	N	.....	3.9430	4.3782	.....	3.5226	3.5372	.....	5.2366	5.4044
	12	UN	.....	3.9043	4.4372	.....	3.6674	3.6790	.....	5.1215	5.3107
	16	UN	.....	3.8360	4.3417	.....	3.7398	3.7497	.....	4.9852	5.2098
2 5/16	16	N	.....	3.9329	4.4983	.....	3.9563	3.9673	.....	5.1041	5.3418
2 3/8	12	UN	.....	4.1185	4.6880	.....	4.1032	4.1158	.....	5.3920	5.6021
	16	UN	.....	4.0409	4.5895	.....	4.1797	4.1910	.....	5.2427	5.4867
2 7/16	16	N	.....	4.1505	4.7478	.....	4.4093	4.4209	.....	5.3813	5.6317
2 1/2	4	UNC	4.4107	4.4946	4.6975	3.9330	3.9510	3.9711	5.7120	6.0734	6.1978
	8	N	.....	4.3966	4.8889	.....	4.4026	4.4193	.....	5.8157	6.0017
	12	UN	.....	4.3420	4.9434	.....	4.5644	4.5776	.....	5.6774	5.8984
	16	UN	.....	4.2585	4.8372	.....	4.6449	4.6568	.....	5.5199	5.7767
2 5/8	12	UN	.....	4.5655	5.1988	.....	5.0500	5.0639	.....	5.9628	6.1947
	16	UN	.....	4.4761	5.0849	.....	5.1347	5.1472	.....	5.7971	6.0667
2 3/4	4	UNC	4.8898	4.9864	5.2128	4.8594	4.8802	4.9029	6.2822	6.6812	6.8196
	8	N	.....	4.8489	5.3985	.....	5.3806	5.3995	.....	6.3893	6.6015
	12	UN	.....	4.7891	5.4541	.....	5.5601	5.5748	.....	6.2482	6.4910
	16	UN	.....	4.6937	5.3326	.....	5.6491	5.6621	.....	6.0744	6.3565
2 7/8	12	UN	.....	5.0064	5.7033	.....	6.0944	6.1097	.....	6.5274	6.7748
	16	UN	.....	4.9032	5.5722	.....	6.1875	6.2011	.....	6.3433	6.6381
3	4	UNC	5.3694	5.4778	5.7329	5.8840	5.9072	5.9327	6.8550	7.2903	7.4428
	8	N	.....	5.2956	5.9034	.....	6.4562	6.4774	.....	6.9563	7.1962
	12	UN	.....	5.2297	5.9564	.....	6.6536	6.6696	.....	6.8125	7.0705
	16	UN	.....	5.1204	5.8195	.....	6.7509	6.7651	.....	6.6201	6.9277
3 1/8	12	UN	.....	5.4530	6.2135	.....	7.2374	7.2540	.....	7.0976	7.6619
	16	UN	.....	5.3377	6.0669	.....	7.3388	7.3537	.....	6.8970	7.2172
3 1/4	4	UNC	5.8474	5.9661	6.2481	7.0065	7.0319	7.0601	7.4242	7.8960	8.0633
	8	N	.....	5.7446	6.4115	.....	7.6302	7.6542	.....	7.5300	7.7942
	12	UN	.....	5.6762	6.4686	.....	7.8457	7.8630	.....	.....	.....
	16	UN	.....	5.5550	6.3143	.....	7.9513	7.9668	.....	7.1739	7.5068

$$A_t = \pi D_t^2$$

$$D_t = D_B - 2\left[\frac{9H}{16} + \frac{T_{pe}}{2} + \frac{Q}{2}\right]$$

$$A_t = 0.7854\left[D_B - \frac{0.9743}{n} - (T_{pe} + Q)\right]^2 \quad (3)$$

The area A_t in Eq (3) for the various series of external threads is shown in the table.

Strength of threads

Using the values for shear and tensile areas developed above, minimum strength for internal and external threads is given by the following basic formulas:

$$P_s = A_s L S_s \quad (4)$$

$$P_s = A_s L S_s \quad (5)$$

$$P_t = A_t S_t \quad (6)$$

When both the internal and ex-

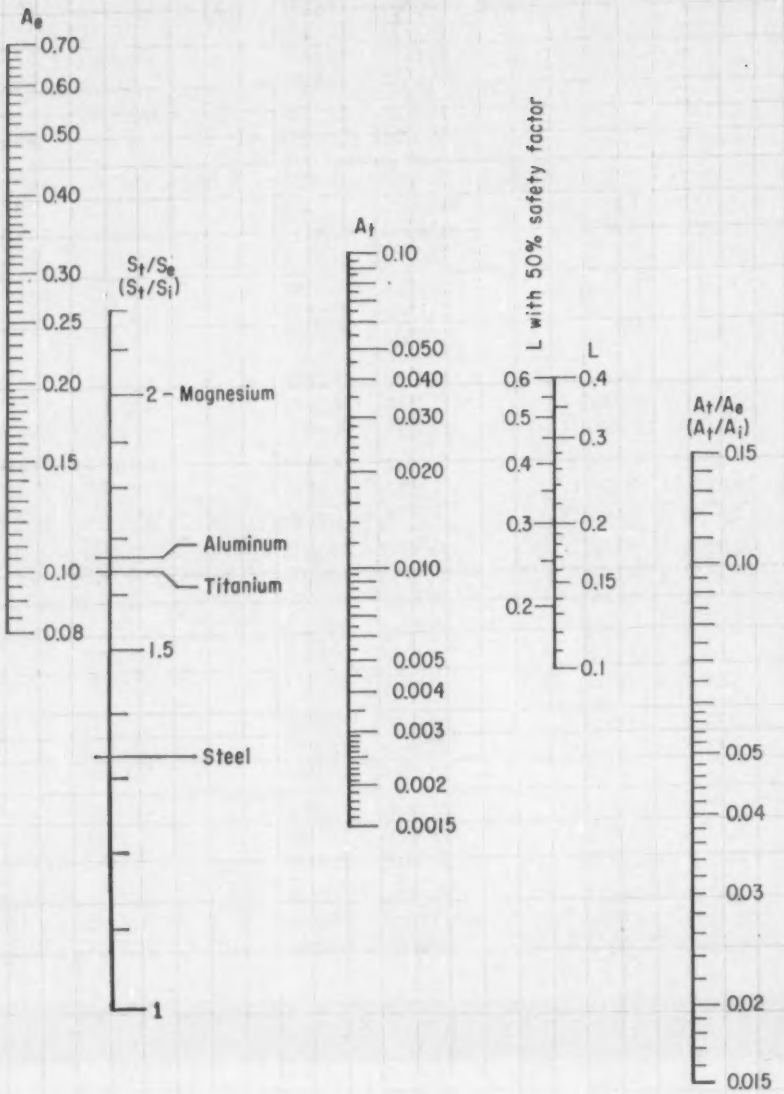
Shear and tensile areas of screw threads... *continued*

THREAD SIZE	n	SERIES	A_s FOR CLASS: 1A	2A	3A	A_t FOR CLASS: 1A	2A	3A	A_t FOR CLASS: 1B	2B	3B
3 3/8	12	UN	.....	5.8922	6.7164	.....	8.4780	8.4961	.....	7.6532	7.9504
	16	UN	.....	5.7530	6.5520	.....	8.5872	8.6039	.....	7.4312	7.7866
3 1/2	4	UNC	6.3185	6.4582	6.7646	8.2270	8.2555	8.2861	7.9947	8.5035	8.6831
	8	N	.....	6.1969	6.9186	.....	8.9033	8.9282	.....	8.1023	8.3865
	12	UN	.....	6.1152	6.9713	.....	9.1354	9.1542	.....	7.9378	8.2458
	16	UN	.....	5.9695	6.7990	.....	9.2488	9.2661	.....	7.7074	8.0758
3 5/8	12	UN	.....	6.3382	7.2261	.....	9.8173	9.8367	.....	8.2223	8.5413
	16	UN	.....	6.1860	7.0460	.....	9.9348	9.9527	.....	7.9835	8.3650
3 3/4	4	UNC	6.8019	6.9447	7.2810	9.5454	9.5461	9.6102	8.5612	9.1073	9.3048
	8	N	.....	6.6383	7.4253	.....	10.2723	10.3013	.....	8.6675	8.9772
	12	UN	.....	6.5612	7.4809	.....	10.5238	10.5439	.....	8.5069	8.8367
	16	UN	.....	6.4026	7.2930	.....	10.6455	10.6640	.....	8.2596	8.6542
3 7/8	12	UN	.....	6.7678	7.7274	.....	11.2536	11.2750	.....	8.7744	9.1238
	16	UN	.....	6.5966	7.5290	.....	11.3794	11.3991	.....	8.5131	8.9322
4	4	UNC	7.2797	7.4357	7.7970	10.9624	10.9958	11.0324	9.1294	9.7131	9.9234
	8	N	.....	7.0883	7.9311	.....	11.7410	11.7714	.....	9.2365	9.5723
	12	UN	.....	6.9903	7.9819	.....	12.0091	12.0312	.....	9.0585	9.4189
	16	UN	.....	6.8124	7.7756	.....	12.1391	12.1595	.....	8.7885	9.2210
4 1/4	8	N	.....	7.5261	8.4300	.....	13.3065	13.3394	.....	9.7977	10.1667
	12	UN	.....	7.4352	8.4910	.....	13.5938	13.6173	.....	9.6265	10.0093
	16	UN	.....	7.2440	8.2689	.....	13.7320	13.7537	.....	9.3394	9.7987
4 1/2	8	N	.....	7.9740	8.9342	.....	14.9713	15.0062	.....	10.3699	10.7539
	12	UN	.....	7.8801	9.0000	.....	15.2766	15.3016	.....	10.1950	10.5997
	16	UN	.....	7.6756	8.7621	.....	15.4231	15.4461	.....	9.8902	10.3763
4 3/4	8	N	.....	8.4146	9.4372	.....	16.7334	16.7711	.....	10.9275	11.3464
	12	UN	.....	8.3044	9.4993	.....	17.0561	17.0832	.....	10.7420	11.1694
	16	UN	.....	8.0799	9.2418	.....	17.2109	17.2360	.....	10.3998	10.9265
5	8	N	.....	8.8538	9.9468	.....	18.5963	18.6349	.....	11.4903	11.9383
	12	UN	.....	8.7482	10.0079	.....	18.9353	18.9638	.....	11.3090	11.7587
	16	UN	.....	8.5101	9.7344	.....	19.0983	19.1247	.....	10.9484	11.5027
5 1/4	8	N	.....	9.2993	10.4492	.....	20.5526	20.5960	.....	12.0593	12.5294
	12	UN	.....	9.1920	10.5164	.....	20.9125	20.9425	.....	11.8760	12.3480
	16	UN	.....	8.9402	10.2270	.....	21.0839	21.1116	.....	11.4971	12.0789
5 1/2	8	N	.....	9.7360	10.9504	.....	22.6089	22.6552	.....	12.6114	13.1118
	12	UN	.....	9.6358	11.0250	.....	22.9880	23.0194	.....	12.4429	12.9372
	16	UN	.....	9.3704	10.7195	.....	23.1677	23.1967	.....	12.0457	12.4685
5 3/4	8	N	.....	10.1791	11.4514	.....	24.7640	24.8126	.....	13.1783	13.7011
	12	UN	.....	10.0427	11.5086	.....	25.1590	25.1928	.....	12.9597	13.5140
	16	UN	.....	9.7675	11.2120	.....	25.3478	25.3782	.....	12.5442	13.1980
6	8	N	.....	10.6132	11.9511	.....	27.0163	27.0680	.....	13.7357	14.2897
	12	UN	.....	10.4849	12.0160	.....	27.4306	27.4660	.....	13.5245	14.1028
	16	UN	.....	10.1962	11.7046	.....	27.6279	27.6595	.....	13.0907	13.7728

ternal threaded parts are made of materials with the same mechanical properties, the external threads will be the weakest; consequently, the minimum desired strength of the assembly should be based on this critical section. If the externally threaded part is made from a stronger material than the mating internally threaded part, the internally threaded part may fail in shear before the externally threaded part fails in tension. In such a case, the strength of each part should be checked with the equations and areas given here so that length of thread engagement will meet the design requirements.

To find the length that will develop the full tensile strength of the external thread, Eq (4) and (6), and (5) and (6), are set equal to one

4..Strength ratios for small screws



another so that L appears as the ratio.

$$L = \frac{A_e S_t}{A_e S_e} \quad \text{for the external thread} \qquad (7)$$

$$L = \frac{A_e S_t}{A_t S_t} \quad \text{for the internal thread} \qquad (8)$$

For threaded parts made from materials with identical mechanical properties only Eq (7) need be used, but when the materials differ the length of engagement should be checked with both Eq (7) and (8).

The nomographs, Fig 4 and 5, are helpful in solving the ratio S_t/S_e for some materials. They can also be used for threaded parts made from materials with different mechanical properties. For example, if the internal thread is made from the weaker material, the A_e scale on the applicable nomograph can be used to find A_t, and thus give the ratio S_t/S_t in place of S_t/S_e.

Assume that it is desired to find the length of engagement to develop a shear strength that will exceed the tensile strength of 1-16UN-2A thread by 50% for an assembly made of 7075-T6 aluminum. Using the Fig 5 nomograph, trace the following steps, which are also marked on the nomograph:

1. From the table, $A_e = 1.6662$. Locate this on A_e scale.
2. From the table, $A_t = 0.6831$. Locate this on A_t scale.
3. Join these two points to intersect A_t/A_e scale.
4. Locate aluminum on the S_t/S_e scale.
5. Connect the points found in steps 3 and 4 above to give $L = 1.02$ with a 50% safety factor. With a shear strength that just equals tensile strength, the length of engagement is $L = 0.69$.

Example 1

A shaft with a 1-12UNF-2A thread is assembled with a fixed mating piece having the same class thread so that $L = 0.50$ in. What is the minimum shear strength of the external thread if both pieces are made from aluminum with 37,000-psi shear strength?

SOLUTION

From the table:
$A_e = 1.6676$, which gives:
$P_s = (1.6676)(0.50)(37{,}000)$
$= 30{,}850$ lb

Example 2

Design objective calls for a threaded engagement of 1.58 ± 0.05 in. using a special thread of size 1½-32NS-class 2. What is the shear strength of this assembly if the internally threaded part is made of aluminum with shear

strength of 46,000 psi, and the externally threaded piece is made of aluminum with shear strength of 22,000 psi?

SOLUTION

Since the externally threaded part is the weakest, the minimum shear area for it must be checked. Using procedure described above, the following factors are determined:

$$T_{di} = 0.0074; \quad Q = 0.0012;$$
$$T_{De} = 0.0040; \quad d_i = 1.4763; \quad n = 32$$

Substituting these values in Eq (1) gives:

$$A_s = 1.4763[2.3562 - 1.8138(32)(0.0074 + 0.0012 + 0.0040)32] = 2.3944$$

which leads to:

$$P_s = (2.3944)(1.53)(22{,}000) = 80{,}600 \text{ lb}$$

For **reprint** of above article, just check 639 on one of the Reader Service cards found in this issue.

EDITOR'S NOTE: The author is indebted to Mr Peter Kiako for his assistance in calculation of the tables. For additional information in threaded fasteners see:

What Torque to Tension Plated Bolts, Dec 5 '60, p 73—Shows how for a given torque, tension will vary inversely with the coefficient of friction—which is affected by whether plating goes on bolt, nut, or washer.

Vibration Resistance of Thread-Locking Devices, Oct 10 '60, p 58—Gives new test method for rating ESNA type locknuts and compares results with plain nuts.

Test Results Guide High-Temperature Design of Bolted Assemblies, Sep 30 '57, p 79—Recommends materials for bolts and structures up to 1350 F; gives test results for computing effects of heat expansion.

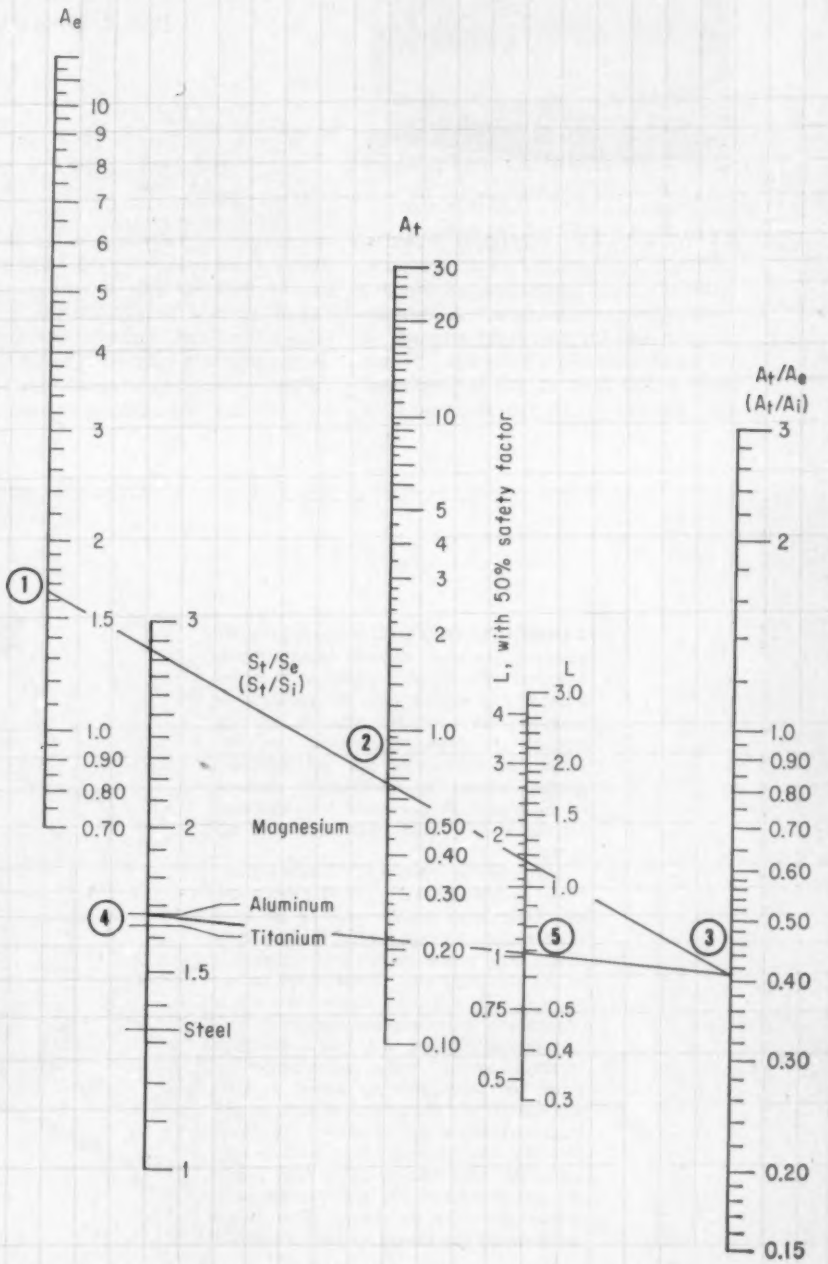
How to Select Threaded Inserts, May 22 '61, p 46—Gives answers to: Why use an insert? What types are available? What factors govern their selection? How do you determine whether a particular insert meets the given strength requirements, and which is most economical?

Don't Overlook Near-standard Fasteners, Jan 19 '61, p 75—How special modifications, varying only slightly from standard, can save assembly time and money far outweighing cost.

55% Thread Depth Makes Beryllium Bolts Practical, Nov 14 '60, p 75—Large radius root thread increases fatigue strength without losing strength. It promises improvements in fasteners—beginning with beryllium.

Bolt Threads with Large-Radius Roots, Nov 9 '59, p 89—standards for 75% and 55% thread depths.

5.. Strength ratios for large screws



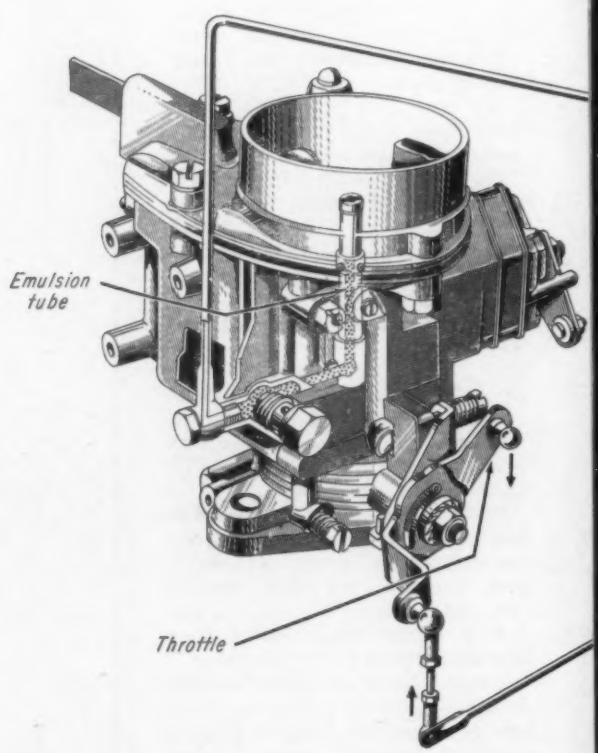
Metered oil feed

Oil pump responsive to speed and load provides optimum gas-oil mix.

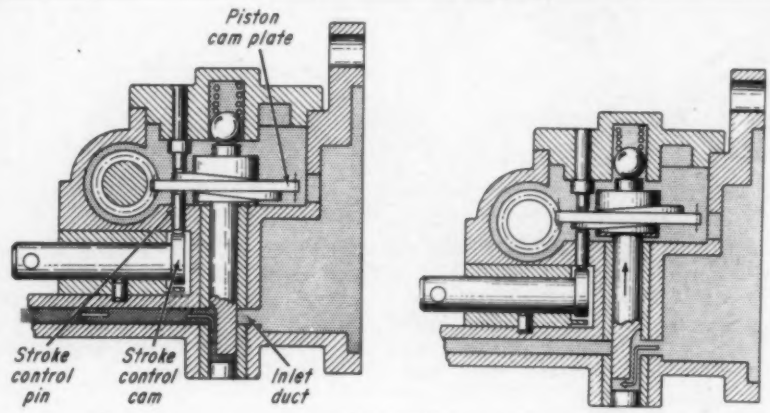
TWO-CYCLE, 3-cylinder engines, used in imported passenger cars, normally mix lubricating oil directly with gasoline in the tank. A measure is provided for the right amount of oil to be added to a full tank. If less than a full tank of gas is purchased the amount of oil required must be calculated and measured by the driver. This creates problems since the driver usually ends up with part of an open can of oil left. In addition the oil-gas ratio is fixed and is usually too oil rich for starting and light loads resulting in excessive smoking and spark plug fouling. Oil injection system reduces the oil-gas ratio for normal driving to 40:1, as low as 200:1 depending on load and engine speed. Automatic oiler provides precise oil-gas ratio required for two stroke, gas engines used in DKW and Auto-Union front wheel drive, autos produced by Auto Union, GMBH, Ingolstadt, Donau, Germany.

LUBRICATING OIL is in a four-quart reservoir in the engine compartment. Metered oil supply is piped to the carburetor and mixed with the gasoline as it enters an emulsion tube in the air stream. A single mechanical link between the carburetor and oil injection pump provides the load-sensing element of the system. Engine speed is transmitted by the V-belt drive which operates the pump.

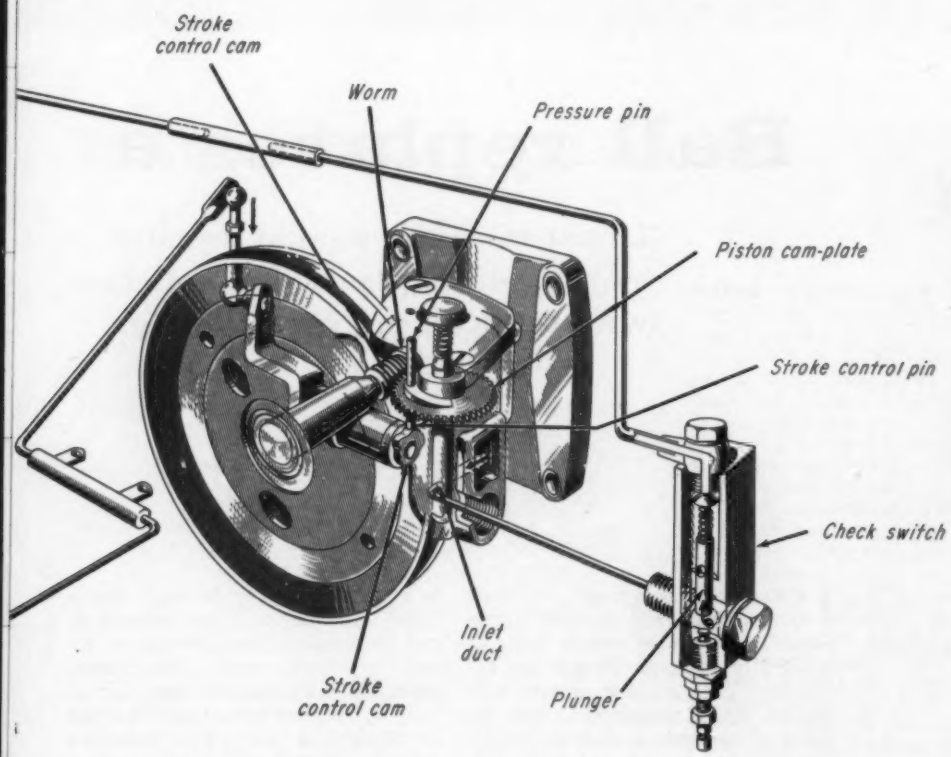
Heart of the injector is the piston cam-plate unit which meters and pumps the oil. Gear teeth on the edge of the cam plate engage a worm on the V-belt pulley shaft. The piston is the shaft extension of the cam-plate axis. Total piston movement is only 0.070 in. so that the worm engagement variations are negligible. The cam-piston rotation speed is a function of engine speed. A slot in the piston exposes an inlet duct to admit a fixed amount of oil from the oil tank to the pump cylinder at each rotation. As piston rotation continues the inlet port is covered, the nose of the plate cam passes the stroke-control pin and the piston is driven down by its spring. This forces oil through the tubing to the carburetor.



ends hand mixing



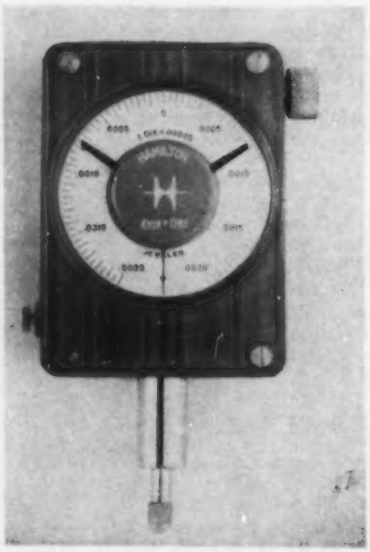
STROKE-CONTROL CAM position is set by linkage from the throttle. When the throttle is opened wide, as in acceleration or under heavy load, the cam raises the stroke-control pin, lifting the cam plate and piston to admit additional oil when the inlet port is exposed. This increases the flow of oil to the carburetor under heavy load conditions. A warning lamp on the dashboard lights up when insufficient oil pressure permits the plunger in the oil supply check switch to make electrical contact.



Pinch valve for

Isolating stream of irritating gas prevents contamination of riot-busting gas gun.

PRISONER of war riots in the Korean conflict pointed up the need for a mob control method that would not inflict permanent bodily harm. One solution, irritant gases dispensed by pressure from pack-mounted tanks. Irritant Gas Dispenser, Portable, E15R2 was developed for military and civilian agencies by the Product Engineering Division, US Army Chemical Corps, Engineering Command, Maryland.

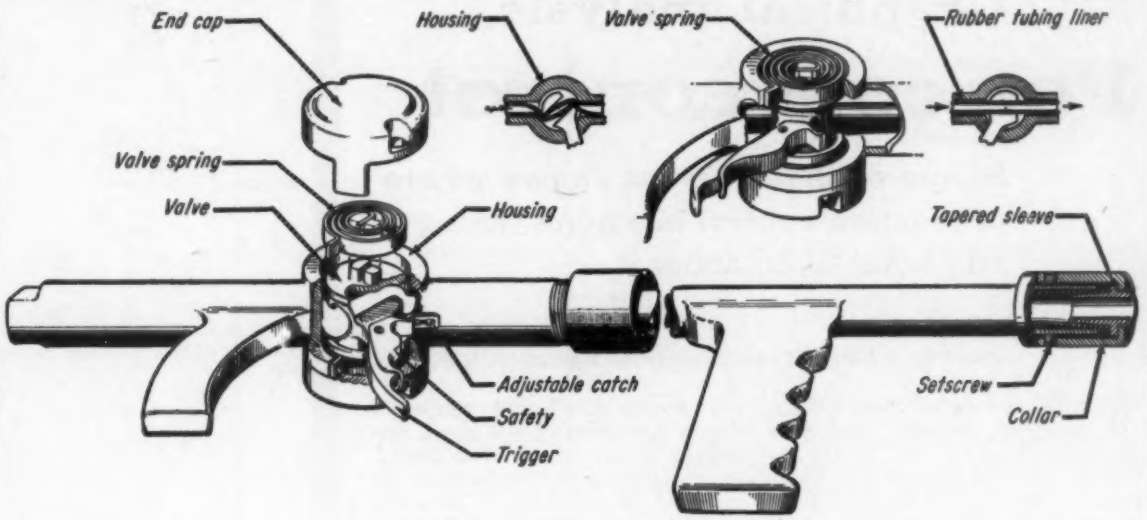


Ball replaces a

Linear-to-rotary motion transfer by ball bearing is used in indicator with 0.000,02 in. repeatability.

LOW-COST shockproof dial indicator has fully jeweled movement, an adjustable spindle force of either 2 or 4 oz, an integral fine adjustment plus a cable release type spindle lifting mechanism. The expense of conventional rack and pinion gearing, special cams, and leaf spring mounts are eliminated without sacrificing accuracy. Two gear sectors and two pinions comprise the entire movement. The self-contained movement can be removed from the case for repair or replacement. The instrument is calibrated in divisions of 0.000,05 in. and has a range of 0.004 in. Kwik-Chek Micro Dial Indicators Model 1 4-005-2 and -3 are produced by Hamilton Watch Co, Industrial Division, Lancaster, Pa.

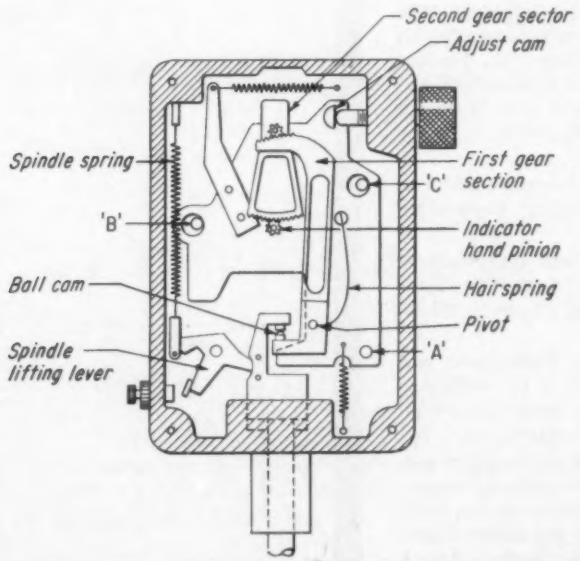
gas flow control



GAS GUN has several basic problems which were solved by a rubber liner tube and a pinch valve. The tube permits positive gas control without complex seals which would be difficult to replace in the field. The uninterrupted tube also isolates the flow-control mechanism from the gas, eliminating contamination and corrosion. A simple nozzle fitting seals the tubing liner to the barrel and keeps gas from seeping into the gun.

Pinch valve is a short cylinder with a hole bored through its diameter. Gas dispensing tube passes through the hole and is pinched closed when the torsion springs rotate the cylinder CCW. To open the valve, the cylinder is rotated CW by a trigger. Gas pressure straightens the tube and provides smooth flow through the valve area.

rack and pinion



WHEN THE SPINDLE is forced upward the anvil rises and the ball cam follows as the first gear sector is rotated CW by the hairspring. The first gear sector is meshed with a pinion on the second gear sector and rotates it CCW. The second gear sector rotates the indicator hand pinion CW to show an increased reading on the dial. Motion is arrested at full range when the second gear sector strikes a support plate post. Further travel of the spindle in the upward direction has no effect on the ball cam or movement. The greatest force that can be applied to the movement is limited to the hairspring preload. Spindle spring forces the anvil down through the lifting lever to keep the spindle in contact with the part being measured.

For fine adjustment the entire movement is pivoted on pivot 'A'. The mounting holes at 'B' and 'C' are larger than the mounting screws permitting a slight rotation of the movement plate. When the fine adjustment knob is screwed inward it forces the fine adjustment cam to the left rotating the plate CCW. This lowers the ball cam pivot and reduces the indicated reading. The restraining springs hold the adjustment can against its screw.

Graphical analysis

For cost control

Shape of these curves shows where production control has gone wrong—and what to do about it.

HECTOR E FRENCH, chief, engineering publications, Sanborn Co

WHEN a product is made in large quantities, common sense says that manufacturing cost should be identical for each identical unit. Common experience proves otherwise. Even when manufacturing conditions appear to remain steady, cost per item usually fluctuates from day to day and month to month. This difference between theory and practice is worth a closer look. It may reveal hidden costs, unnecessary delays, poor production control. That is the purpose of the diagnostic curves shown on these pages.

Cost data are plotted by carrying the traditional cost analysis a step further than usual. The customary monthly average-cost-per-unit figures are a partial measure of cost control but they don't go far enough. Because they are simply an average, computed by dividing total manufacturing cost by the number of units produced, they indicate only the relative operating efficiency compared to previous months. But they cannot suggest how to do better in the future; they cannot hint at the amount of cost control that may or may not exist; nor can they point to possible cures for your cost-control diseases.

The curves will do all of these. The first step is to break down the monthly cost figure into actual cost-per-unit values, rather than an average. The units can be any convenient production item—a complete product, a stage of amplification, a 1-sq-ft area of a finished drawing. There should be at least 40 to 50 of these basic units in each month's production. Be sure to use comparative cost figures for all units—don't include overhead in some and not in others, for example.

Now plot a curve showing the number of units produced in each of several predetermined cost categories. Choose cost intervals that give a reasonably broad curve covering from 5 to 10 categories. If cost intervals are too wide, the curve will be artificially peaked; if too narrow, it will be artificially flattened. Either way, you run the risk of a false interpretation. To facilitate comparison between months, it is often helpful to plot the *y* axis in terms of percentage of total production, rather than in actual units produced.

From the spread, position, and shape of this curve, and from the presence of points that fall well outside it, you can draw conclusions about the effectiveness of your cost control. These features, and the interpretation of each, are shown in the table at right. Remember, though, that these interpretations and recommendations are not a replacement for good judgment. The curve diagnosis is not conclusive, it only indicates where to look. Finding true reasons for poor cost control and doing something about them is still an administrative responsibility.

EDITOR's NOTE: For more information about administering engineering costs, see:

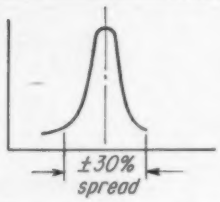
Cost of Research and Development Projects, Mid-Oct '55, p A9—Gantt chart techniques and graphs that help to estimate costs.

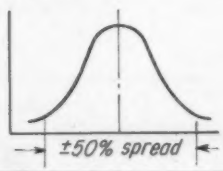
Cutting Costs on Prototypes and Small Lots, Mar '56, p 169—How to reduce cost without restricting design or infringing on standards.

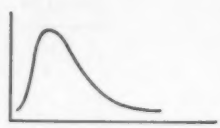
A Simple Approach to Cost Estimating, July '53, p 178—An easy way to predetermine manufacturing cost while the product is still in the design stages.

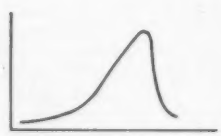
—Charles J Lynch

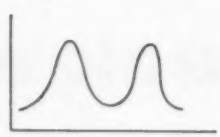
THESE CURVES

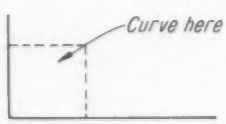


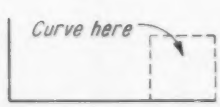


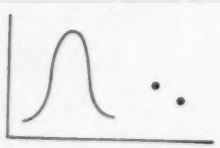










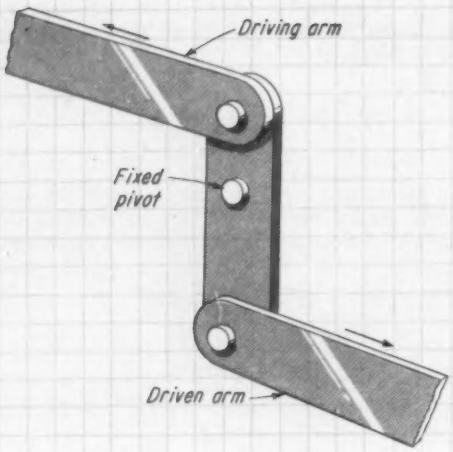


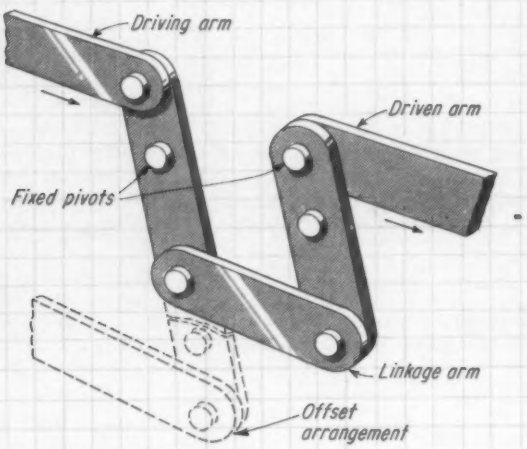
MAY MEAN	TO IMPROVE COST CONTROL
Cost control is good. This is ideal curve shape. Spread will usually be about ±30% of medium value or better.	Look for good cost-control practices. Record as many details as possible for reference in case control starts to slip in future months.
Cost control is poorer than curve above, other things being equal. Percentages are only estimates; the line between "good" and "bad" control depends on the situation. Broad curve may also be caused by wide variation in nature of work, or poor selection of basic units.	Look for differences between high-cost and low-cost work. Better control may be possible by dividing the work into two or more separately controlled categories.
Most units are being made at reasonable cost but some still cost more than is apparently necessary.	Find reasons for high-cost work. See if methods for low-cost units can be applied to high-cost units. Trouble may also be caused by incorrect costing.
Many units are being made at high cost, despite low cost on some units.	Determine cause of low-cost units to discover whether the methods can be applied to high-cost units. Trouble may also be caused by added fixed charges on high-cost units.
There are two categories of work, or two groups of workers, or two kinds of working conditions, or cost figures from two sources.	Discover ways to bring high-cost curve down to match the low-cost curve. To get realistic results, it may be necessary to treat the work as two separate categories.
Costs are low. This, of course, is best location for curve of any shape.	List reasons for low cost. Make note of all details for reference in case costs start to rise in future months.
Costs are high. This is worst location for any curve.	Look for fixed charges that affect all work: too much set-up time, incorrect costing, excessive overhead, too much red tape.
Cost of certain units are out of control. The points outside the curve can be either below or above the curve. If numerous, they may indicate poor control of costs, or another category of work.	Determine reason for spurious points. If points are above curve, look for ways to prevent recurrence. If points are below curve, they may represent low-cost procedures worth studying.

8 Basic Push-pull

These arrangements are invariably the root of all linkage devices

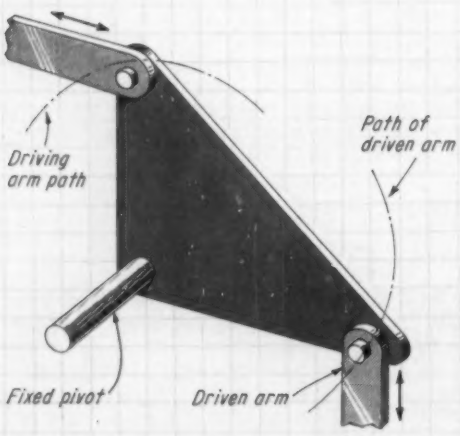
FRANK WILLIAM WOOD JR
President, Advanced Design Inc, Vienna, Va

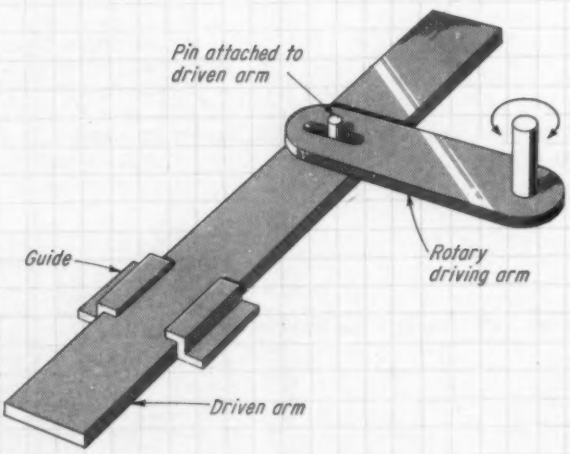




1 **FIXED PIVOTS** on arm lengths are located to control ratio of input and output movements of this push-pull-actuated linkage. Mechanism can be either flat bars or round rods of adequate thickness to prevent bowing under compression.

2 **PUSH-PULL LINKAGE** for same direction of motion can be obtained by adding linkage arm to previous design. In both cases, if arms are bars it might be best to make them forked rather than merely flatted at their linkage ends.



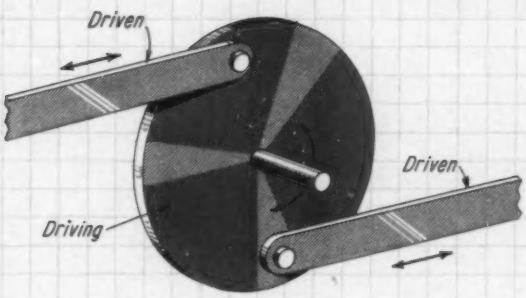


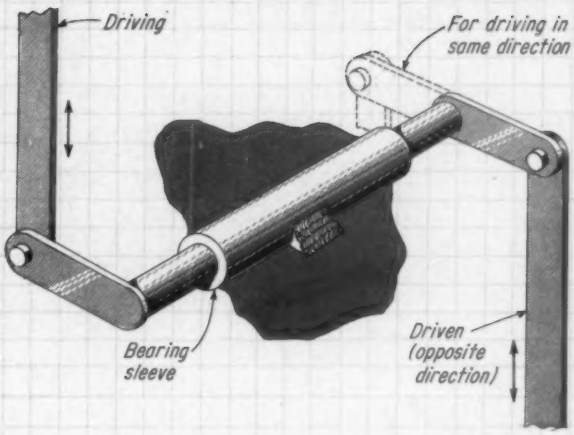
5 **VERTICAL OUTPUT MOVEMENT** from horizontal input is gained with this push-pull linkage. Although the triangular-shaped plate could be substituted by an L-shaped arm, the plate gives greater freedom of driving- and driven-arm location.

6 **FOR LIMITED STRAIGHT-LINE** 2-direction motion use this rotary-actuated linkage. Friction between the pin and sides of slot limit this design to small loads. A bearing on the pin will reduce friction and slot wear to negligible proportions.

Linkages

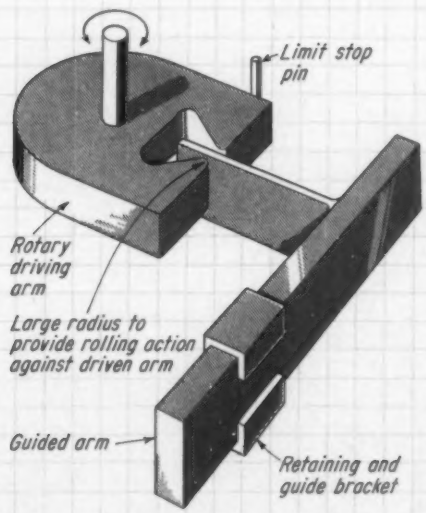
PRODUCT ENGINEERING
NOVEMBER 27, 1961

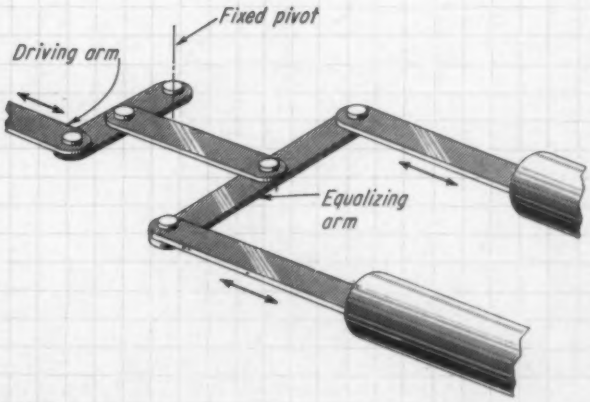




3 **ROTARY-ACTUATED LINKAGE** gives opposite direction of motion and can be obtained by using 3-bar linkage with pivot point of middle link located at midpoint of arm length. Disk should be adequately strengthened for heavy loads.

4 **SAME-DIRECTION MOTION** is given by this rotary-actuated linkage when end arms are located on the same sides; for opposite-direction motion, locate the arms on opposite sides. Use when a crossover is required between input and output.


Limit stop pin
Rotary driving arm
Large radius to provide rolling action against driven arm
Guided arm
Retaining and guide bracket



7 **THIS ROTARY-ACTUATED** linkage for straight-line 2-direction motion has rotary driving arm with a modified dovetail opening that fits freely around a flat sheet or bar arm. Driven arm reciprocates in slot as rotary driving arm is turned.

8 **EQUALIZING LINKAGE** here has an equalizing arm that balances the input force to two output arms. This arrangement is most suitable for air or hydraulic systems where equal force is to be exerted on the pistons of separate cylinders.

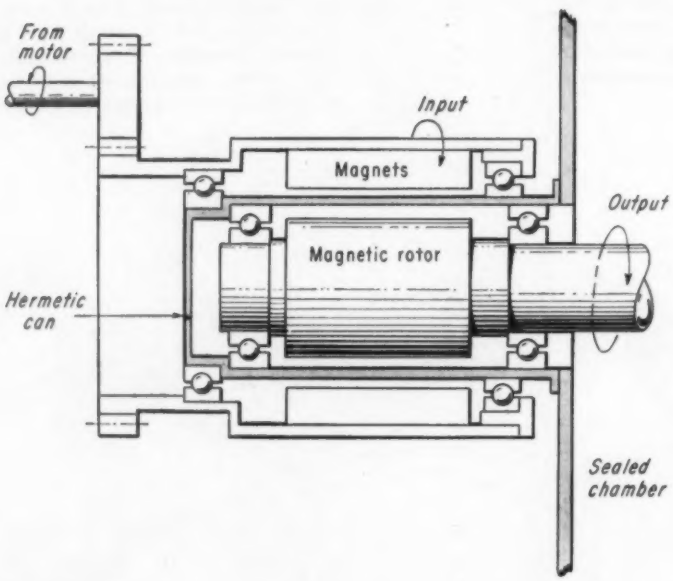
More data on....

Hermetic magnet couplings

The inventor of this coupling, D A Guerdan, recently updated his previous equations (PE—Apr 28 '58) with corrected constants based on new tests.

FRANK YEAPLE, associate editor

Motor-driven magnetic coupling



Permanent-magnet segments in the field assembly create a rotating magnetic field. The field penetrates a semistainless can to drive the rotor. The sealed chamber has no internal electrical connections—the motor is external. Pressure-tight sealing of the enclosure is simplified because the only joint is at the mounting flange.

YOU can transmit rotating power through a thin metal wall with simple magnetism. This eliminates leaking shaft seals, but there will be electrical losses induced in the metal separator or can.

Electrical losses at speeds under 1000 rpm are fairly low. Above 1000 rpm, the losses are so high that efficiency must be of negligible importance in proposed applications. Here is a review of the operating principles; and the accompanying performance chart updates the old predicted performance calculations with more accurate figures based on tests.

Operating principles

The inner (driven) rotor is hermetically sealed from the outer (driving) field assembly by a semistainless-steel metal can in the airgap (ordinary magnetic steel is too permeable—the flux leaks between poles). The outer field assembly has Alnico-V permanent-magnet segments between steel pole-pieces, and is geared to an ordinary motor (not shown).

Starting is by induction. The inner rotor has salient poles which act much as rotor bars do in a squirrelcage induction motor, with strong eddy currents producing temporary-magnetic poles that try to follow the rotating outer field.

Running is at synchronous speed. The rotor will stay in the relative posi-

Predicted Performance of Six 1800-rpm Couplings

(4-pole permanent-magnet field; 1000 psi chamber)

ENVELOPE SIZE, IN.						
OD outer sleeve	2.5	3	6	7	9	11
Coupling active lgth	2	2.8	5.5	8	11	13.3
PERFORMANCE						
Running torque, lb-ft (max pull-out)	0.5	1	10	20	50	100
Max transmitted hp	0.17	0.34	3.4	6.9	17.1	34.3
Eddy-current losses, hp	0.06	0.19	1.8	5.6	20.2	76.0
INSIDE DIMENSIONS AND WGT						
Inner rotor OD, in.	1.5	2	3.5	4	5.5	7
Can thickness, in. (hermetic wall)	0.045	0.045	0.045	0.062	0.062	0.093
Airgaps, in. (inner and outer)	0.005	0.005	0.010	0.012	0.018	0.025
Wgt of magnet, lb (Alnico V)	0.8	1.6	12.6	25	57	103

tion giving greatest permeability for the field-pole magnetic lines of force. The rotor salient poles stay opposite the field poles and resist getting out of step. If maximum pullout torque is exceeded, the coupling will jump from pole to pole, resulting in theoretical zero net torque. Therefore operation is synchronous or the method won't work at all.

The principle here is similar to that of a reluctance motor, except that in the motor the field poles are stationary, and ac current in the field windings generates the rotating magnetic field. Design details on the hermetic can, inner rotor, and outer field are given in the Apr 28 '58 article, listed in "Editor's Note," and will not be repeated here.

Eddy-current losses in the hermetic can vary with rpm^2, and are extremely high above 1000 rpm. The relationship for power loss is:

$$P_L = \frac{KRLN^2 B_M^2 D^2}{\rho}$$

where

- P_L is loss in kw
- K is a constant, 10.9×10^{-10}
- R is can thickness, in.
- L is active coupling length, in.
- N is speed, rpm
- B_M is max flux density, assumed 50,000 lines/sq in.
- D is can dia, in.
- ρ is resistivity, assumed 66 microhm cm

In the previous article, the loss constant K was predicted to be 3.5×10^{-10}. Later work on actual high-speed couplings has established a much higher value: $K = 10.9 \times 10^{-10}$. This increased loss will have a serious effect on performance: in the old example for an 1800-rpm 100-lb-ft coupling, the loss should have been 76 hp instead of 24.3 hp. Here is the reworked example:

100 lb-ft, 1800-rpm magnetic coupling:

$$P_L = \frac{(10.9 \times 10^{-10})(0.093)(13.3)(1800)^2(50)^2(7)^2}{66}$$

$$= 56.4 \text{ kw (76 hp)}$$

Power output is:

$$\frac{T \times \text{rpm}}{5250} = \frac{100 \times 1800}{5250} = 34.3 \text{ hp}$$

Friction and windage losses might be 5%, therefore coupling efficiency is

$$\frac{34.3}{76 + 34.3} - \frac{5}{100} = 26.1\%$$

(In the old example, coupling efficiency was 53.5%.)

Predicted running performance for the same 100-lb-ft coupling at lower operating torques but still at 1800 rpm is given in the table above. Same value of $K = 10.9 \times 10^{-10}$ is used for each calculation. (Note: none of these specific couplings has actually been built: data are prorated from prototypes that have similar speed and output.)

EDITOR'S NOTE: Current article is sequel to this previous article by D A Guerdan, Bettis Atomic Power Lab, Westinghouse Electric Corp:
Hermetic Magnetic Couplings For Sending Power Through A Wall, April 28 '58, p 98—Author describes invention of 50-rpm magnetic coupling for nuclear applications, and estimates performance of 1800-rpm version.

Non-rotating magnetic hermetic coupling is described in this recent article:
Linear Motion In Sealed Systems, Nov 21 '60, p 100—Four designs of canned motor-screw and jack for nuclear applications are given. Two have rotating screws; two have linear stepping motion. All can be pressurized.

For helpful data on permanent magnets that might be adaptable to hermetic-coupling design see: **What You Should Know About New Magnets,** Dec 2 '57, p 34; **Ceramic Magnets,** Dec. 8 '56, p 143; **Holding-magnet Design,** Sept 30 '57, p 94; **"Cunife Magnets,"** Dec 2 '57, p 8; **"Plastic-bound Magnets,"** Apr 56, p 182.

Magnetic principle of couplings is explained in this recent article:
Put Eddy Current to Work, Oct 16 '61, p 93—The theory and application of the eddy-current effect, with many interesting applications including couplings.

Practical applications of

Driverless vehicles

Cable-guided buses, ore trucks and warehouse tractors capable of stopping and starting on signal are first step toward the automatic highway.

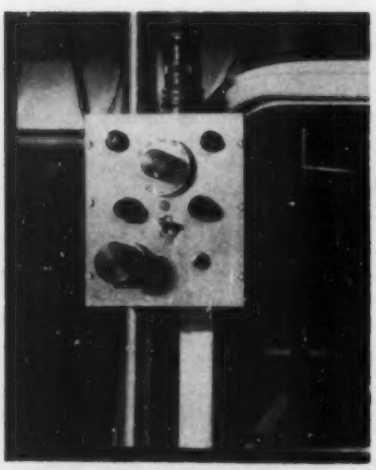
THE era of self-guided passenger vehicles rolled closer with the demonstration of an automatic bus in Dallas, Texas, before the American Transit Association. Built by Barrett-Cravens and based on an electronic system designed by its subsidiary, Barrett Electronics, the bus moved through its paces with sufficient deftness to interest the Chicago Transit Authority in putting the buses into service by 1964.

The vehicle was a 45-passenger city bus—the standard model supplied to the Chicago Transit Authority by Flexible Co of Loudonville, Ohio. The controls, added by Barrett, included a box with a dial numbered 1 to 10. In the public demonstration, passengers simply flipped the dial to a number and pushed the "start" button. Then, a small dc motor pulled the accelerator pedal down and the bus took off at 12 mph, following an electric guide wire embedded in concrete.

The guide wire—in this case a 900-ft oval—set up a magnetic field which was detected by a bar beneath the bus. At one point in the oval, the guide wire was looped to set up an anomaly in the magnetic field. This disturbance was detected and counted by a sensing device on the bus each time it passed over. When the bus passed the loop the number of times dialed by the passenger it automatically stopped.

Barrett intended this demonstration as a very simple illustration of what can be done with a guide wire. The same system and concepts, with somewhat more complex electronics, could stop the bus, open its doors, wait until passengers board, close the doors and start off again.

The electronic system demonstrated at Dallas is similar to those designed by Barrett over the past seven years for warehouse tractors. The company has installed automatic tractors in some of the largest industrial warehouses and in military installations



CONTROL PANEL OF THE BUS demonstrated in Dallas by Barrett-Cravens included this dial with the numbers 1-10. When a passenger pushed one of the buttons, the bus automatically started, circled a loop the number of times marked on the button, then stopped. Big button is emergency stop.

DRIVERLESS TRACTOR here moves down the aisle of a steam turbine generator department. The tractor, following white line, has cargo in tow.

including Tinker, Olmstead, Kelly and Gentile Air Force Bases.

The system is also similar in principle to others developed over the past few years with varying success by some auto companies, including Ford and General Motors. In 1958 Ford demonstrated a tractor with a rectangular sensing device at front to detect and follow a buried guide wire. Ford found that a buried wire is impractical on farms, and switched to a whisker-like sensor, mounted on the front of the tractor. The whisker slides in crop rows and guides the tractor accordingly. Meanwhile, the guide-wire tractors have been used on Ford's proving grounds for endurance tests.

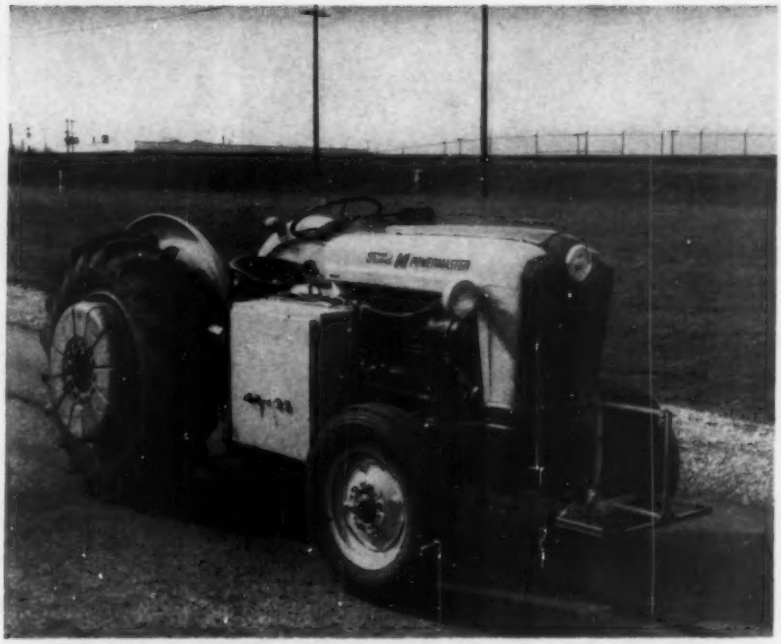
GM's venture into automation began with an ambitious concept for an electronic highway that automatically handles high-speed autos. (*PE June* 20, '60 *p* 17). Developed jointly with RCA, the system has two pickup coils on the front of the car to detect changes in the magnetic field created by the buried cable carrying low-frequency alternating current. Information collected by the pickup coils is fed to an analog computer, linked to a servo system that actuates the vehicle's steering and throttle. The RCA-GM system also includes additional underground circuits that feed information to the analog computer on the presence of cars ahead and behind.

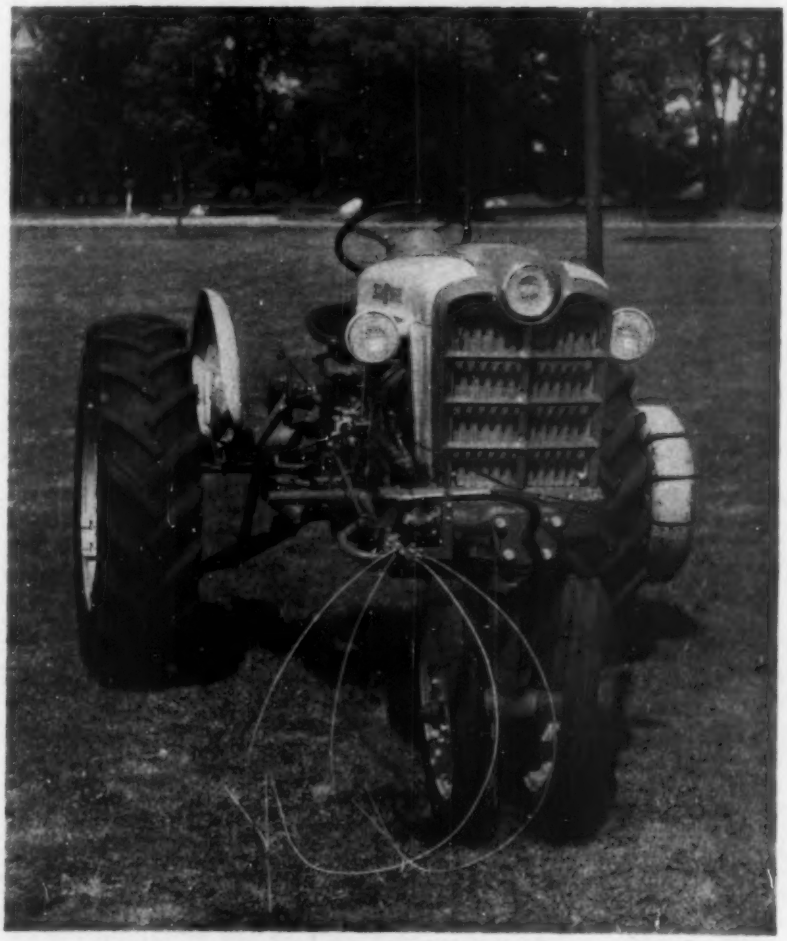
Installation of such a highway would be immensely expensive and is seen only as a long range program. Meanwhile, GM is seeking more modest applications. At present Euclid Div engineers are studying feasibility of installing an automatic roadway at a mine in the Mesabi range. The proposed road traverses a 1½- to 2-mi stretch of rough country between ore loading and unloading points. Ore carriers will be equipped with automatic sensing devices for guiding them over the underground cable and with automatic loading and unloading equipment for handling ore at both ends.

Automation in the warehouse

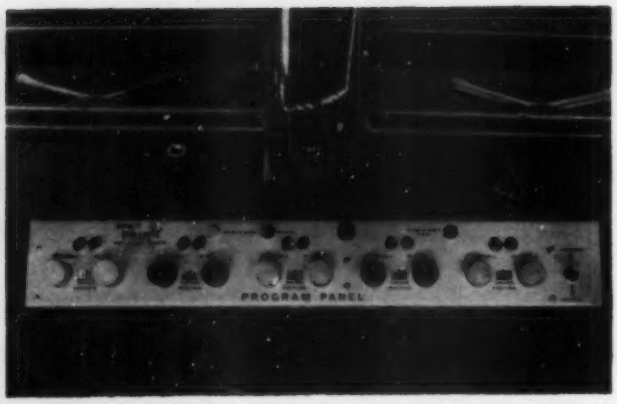
The warehouse tractors developed by Barrett under the Guide-O-Matic trade name come in programmed and nonprogrammed versions. In the simplest systems, tractors shuttle back and forth over a single guide cable. At each terminus, the tractor must be restarted by pushing a button.

Somewhat more complex systems are programmed for sequential or coded operations. In a sequential operation, such as the one installed at Gentile Air Force Base, the tractor





EARLY SELF-GUIDED TRACTORS developed at Ford followed a buried guide wire that was sensed by a front-mounted antenna (above). More recent experimental models detect crop rows and guide the vehicle by a whisker (below).



CONTROL PANEL above is for a tractor operating on a coded system; panel at left is for a sequential system. In the coded system, the operator can choose up to five ports of call with the five selector switches. The sequential panel has 30 toggle switches, each corresponding to a particular station in the plant. Both coded and sequential tractors can be taken off the guide cable and operated manually if a workman needs a tractor in another part of the factory or warehouse. When a coded tractor is put back on the guide wire, it will immediately start seeking the station it was told to visit before the interruption.

runs along a single guide cable having several stations along its route. If the tractor is at station one and an attendant wants to send it to station four, he sets the dial on the control panel and pushes the start button. The tractor, according to instructions, counts off three stations and stops. The Gentile system is 1800 ft long and has 18 programmed stops.

In a coded system, the floor cable includes intersections, switches, sidings, and a number of stations: the tractor always knows where it is in this network, because each station has an identification number in the form of a unique electrical signal. To send a tractor to a particular station, an operator sets station code on the tractor control panel and pushes the start button. The tractor sets off at 2 to 3 mph comparing codes at stations along the way until it finds a match. A workman can program up to five separate destinations at a time with the ten dials on the panel.

One of the most advanced of these systems is operating at a replacement parts warehouse of one of the largest auto manufacturing plants. The system contains 7000 ft of guide wire and serves 27 stations. This network is traveled by six tractors, 150 trailers.

The coded systems have a variety of refinements to smooth their operation. For one, there are coded points in the floor along the route. The tractor reads these to determine the shortest route to its destination. If a station is occupied, the tractor proceeds along the cable, picking out a circular route back to the station. By checking code points on the floor, the tractor selects the shortest route. It continues to circle until the station is empty.

A rather whimsical feature of the coded system is the "charge call." At the end of a day, the battery man pushes a call button, which sends a unique signal out to the tractors. They immediately set off for the charging station, where they line up by the chargers and stop. The battery man plugs charger cables into the tractors and goes home. Next morning he pulls the plugs and the tractors proceed on to the station they had been seeking the night before or to the place where they had been standing.

For safety, all tractors have wraparound bumpers that stop them immediately if they strike an obstacle. The bumper consists of two, flat, flexible, stainless steel sheets (about 22 ga), each 4-in. wide and 6-ft long. The sheets are insulated from one another. On impact with an external object, the outer sheet presses against the inner, completing a 24-v electrical circuit. This stops the motor and clamps on a brake.

Chicago's bus

The bus demonstrated at Dallas, unlike the warehouse tractors, was not conceived as an integrated system. If Chicago does buy automatic buses from Barrett, they will be designed as part of a system oriented toward automatic control rather than a human driver. The system will embrace many of the features developed for automatic warehouse tractors, possibly including even a "gas call."

One of the key design problems anticipated by Barrett is reliability. This is double edged: the Chicago Transit Authority must recommend, and the Illinois legislature approve, a definition of reliability; then Barrett must find a way to meet these standards. Engineers are beginning to mull the problem. One suggested approach is to install parallel control systems, as on many military aircraft.

The automatic buses are being considered for operation on a median strip along Chicago's Southwest Expressway. The median is a protected right-of-way. It's generally agreed that the state of the art is not yet sufficiently advanced to permit both driverless and driver vehicles on the same highway. At first the buses will probably operate as units; later, perhaps as trains pulling up to eight cars.

CTA is investigating the buses because of the potentialities they offer for cutting operating costs. Various installations, particularly the military, have released comparative cost figures for automatic tractors. The economies are considerable. Gentile, for example, reports that wages under its old system amounted to $72,675.20 a year. Wages under the automatic system amount to $50,544 a year. Add to this maintenance costs for the new equipment ($375) and capital costs for the installation amortized over five years ($5417.20) to get total annual operating costs of $56,336.20. This is a saving of $16,399 a year.

For stress analysis

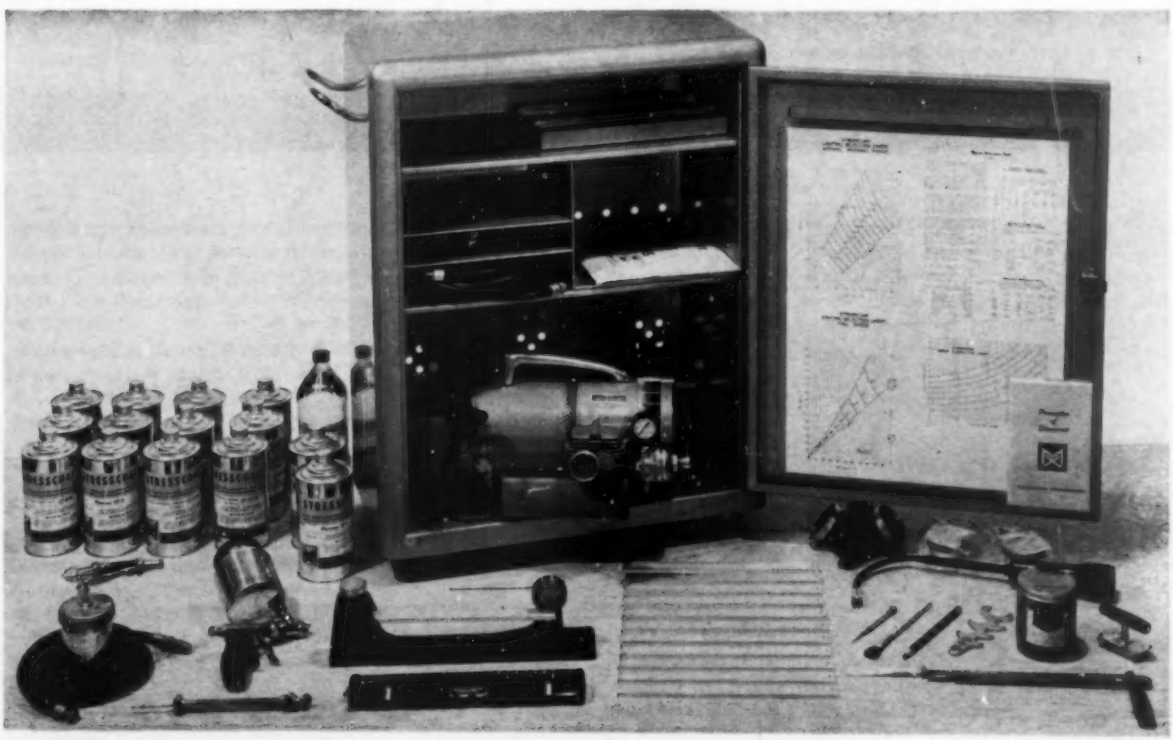
Brittle-coating methods

Second in our continuing series on stress-analysis techniques, here's how to select best coatings, prepare and analyze crack patterns, plus a new micro technique.

NELSON A CRITES, assistant consultant, solid & structural mechanics div, Battelle Memorial Institute, Columbus, Ohio

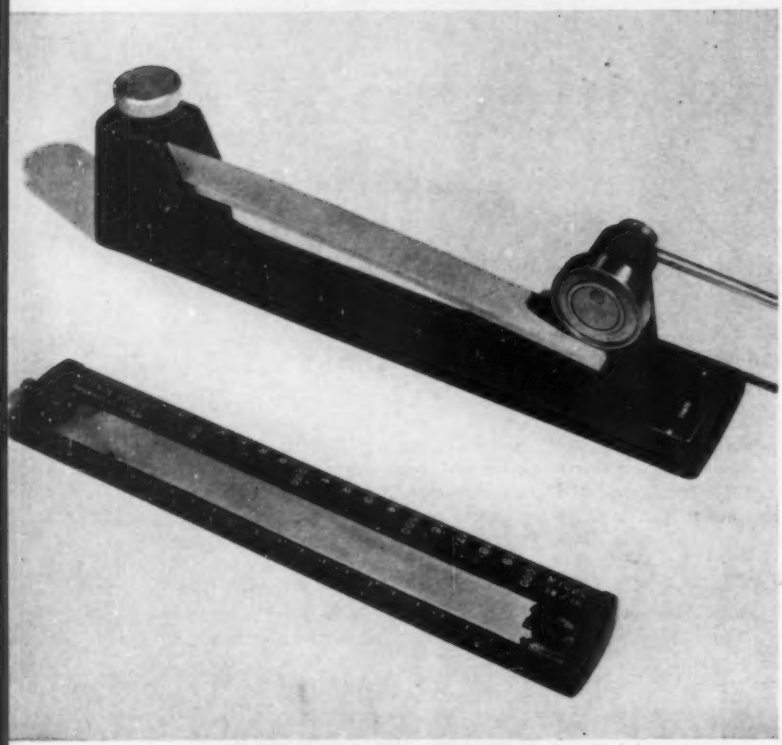
BRITTLE coatings are among the most useful of the various tools and techniques available to the stress analyst today. These coatings indicate stress (or more accurately, strain) by developing crack patterns in the strained areas. The coatings can give both quantitative (magnitude of stresses) and qualitative (direction and location of stresses) results. Large structures can be studied with relative ease by brittle-coating techniques, and they are often employed as "hunting dogs" for locating areas needing more detailed study.

There are two general classes of brittle coatings (Table I). One class has a resin base, and is designed for room-temperature use (0 to 120 F); a second type has a glass base, and was developed for moderately elevated-temperature use (to 600 F). Magnaflux Corp manufactures both classes under the names "Stresscoat" and "Stresscoat All-Temp," respectively. Both are available in formulations of varying strain sensitivity (tendency to



1.. Stresscoat kit SUPPLIED BY MAGNAFLUX CORP (PRICED ABOUT $800):

2..Calibration bars...



...LOADING JIG AND STRAIN SCALE.

TABLE I Guide for selecting

CHARACTERISTICS	RESIN Stresscoat
Usable temperature range, °F	0 to 120
Strain sensitivity (max), microin./in.	500
Approximate range, % strain	0.3
Strain conditions (T = tension, C = compression)	T and C
Required operator experience, 1 to 3 (1 = most experience)	2
For laboratory or field	Both
Test can be performed in oil	No
Estimated time delay, from first operation to first measurement, hr	8 to 18
Typical applications	Machinery, structures, pressure vessels

crack under strain). Both types are most useful when applied by spraying techniques. A kit is available which includes a spray gun and a calibration device, Fig 1, as well as other equipment suitable for many of the usual stress analyses.

Recently, at Battelle, a "micro technique" was developed for stress analyzing small parts such as thin diaphragms and miniaturized gears, and an improved spraying and glazing technique was developed for analyzing large castings (see Table I). Details of these techniques are published here for the first time.

RESIN-BASE COATINGS

The resin-base material, Stresscoat, is relatively easy to apply and can be cured at room temperature. It is employed more extensively than other coatings. The relative ease of application makes it possible to examine whole structures, so that a comprehensive picture can be obtained of the magnitudes and orientations of the principal stresses. On the other hand, Stresscoat is sensitive to humidity and temperature, and is easily scratched.

According to patent information, Stresscoat is compounded primarily from resin plus an additive, with dibutylphthalate as the plasticizer to help control the sensitivity to cracking. To obtain a sprayable material, the components are dissolved in a common solvent, carbon disulfide.

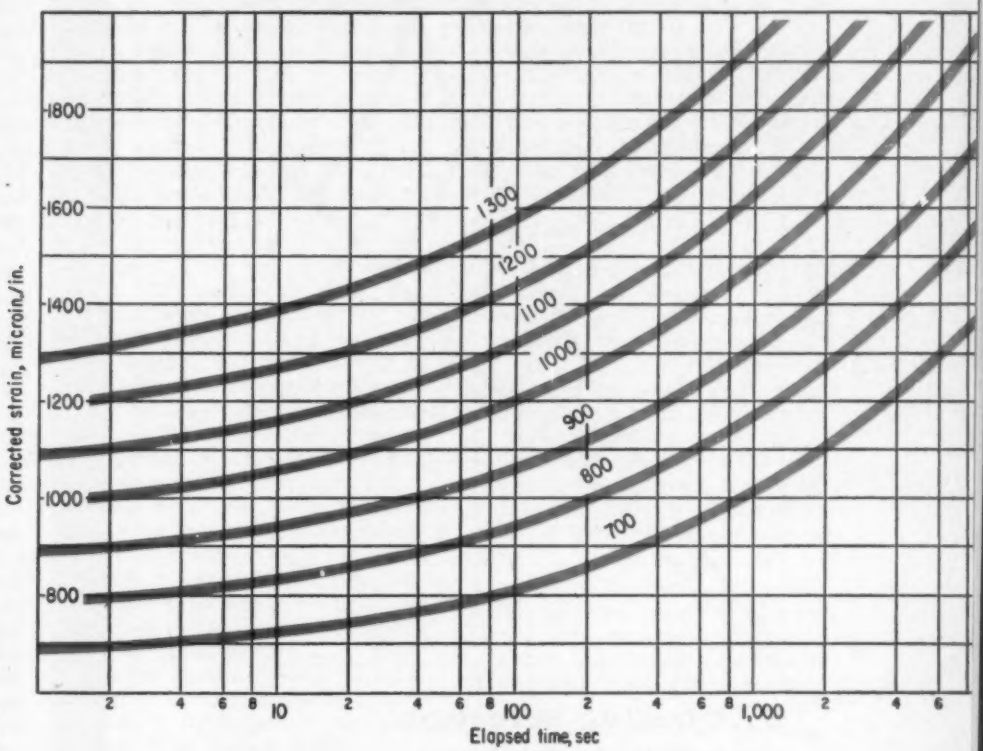
Stresscoat cracks in normal use, if properly selected, when the strain reaches approximately 800 microin. per in. This amounts to a stress of approximately 24,000 psi in steel. In uniaxial stress fields, the cracks in the brittle coatings appear normal to the maximum tensile stresses. In biaxial fields, the cracks appear normal to the direction of the maximum tensile stresses unless the biaxial stresses are approximately equal. In such an instance, cracks may appear in both directions or at right angles to each other.

It is generally true that the greater the number of cracks per unit length, the higher the strain. However, measuring strain by noting the crack density does not give an accurate indication of strain level. A much more sensitive and accurate method is to determine the threshold strain level at which cracks just begin to appear. This level is obtained by means of calibration bars supplied with the Stresscoat kit, Fig 2. The number of bars required depends on the stability of the test conditions. These bars are coated and cured along with the specimen or structure. The strain in the calibration bars is found by deflecting the bars in a loading jig, then measuring the strain cracking sensitivity in

›rittle coatings

SED micro-Stresscoat	GLASS BASED Stresscoat All-Temp
0 to 120	0 to 600
800-1000	200
0.3	0.2
T and C	T only
1	3
Lab only	Both
No	Yes
½ to 2	1 to 10
Thin membranes, small parts, miniature gears	Turbine wheels, engine blocks, heat exchangers

3..Creep correction



a calibrated strain (deflection) scale. Then, in the structure being tested under similar conditions of tension or compression loading, wherever cracks just begin to appear, it can be safely assumed that the strain has reached the same level of intensity that produced similar threshold cracks in the calibration bars.

In most applications, crack formation is only moderately affected by variations in coating thickness and speed of load applications. However, if the load is applied quite slowly, either a creep correction factor must be employed (see chart, Fig 3) or the calibration bars must be loaded at the same rate as the specimen or structure. After the areas and orientations of the highest strains have been outlined, the stresses are derived from the indicated strains by multiplying the strains by the elastic moduli of the materials.

How to select a coating

The coating must have the proper crack sensitivity for successful results. Generally, crack sensitivity varies with the temperature and the humidity conditions under which the test will be made. Stresscoat is available in various sensitivities for various humidity conditions at temperatures ranging from about 0 to 110 F (see charts, Fig 4 and 5).

To determine the temperature and humidity conditions, a sling psychrometer is provided in the kit. Under carefully controlled room conditions, the psychrometer is quite helpful; however, under less rigid conditions an extremely accurate weather prediction might be more practical and easier to get.

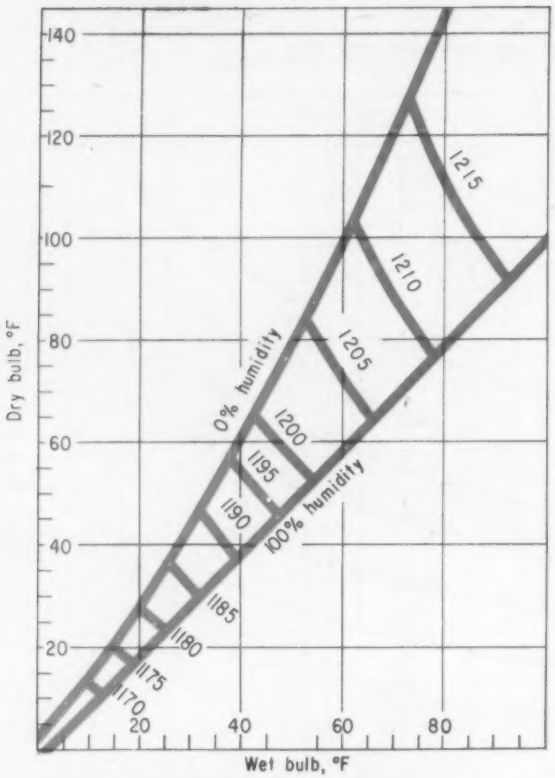
There is some latitude in the selection of the coatings. Although normally the coating will crack at about 800 microin. per in. strain (if selected properly according to Fig 4 or 5), a coating numbered one above or below the middle of the recommended range will still provide satisfactory results. With a coating one number higher or lower, the strain sensitivity to cracking will increase or decrease by about 100 microin. per in. However, if a coating two numbers higher is selected, there will be a strong tendency for the coating to craze crack in the manner characteristic of pottery glazes. A coating two numbers lower, though less sensitive, will still crack, although the cracks will probably close up upon release of the load.

Preparing and coating

After selecting the coating, next step is to prepare the specimen or structure for the coating. In general, the same procedures are used in preparation for stress coating as for any

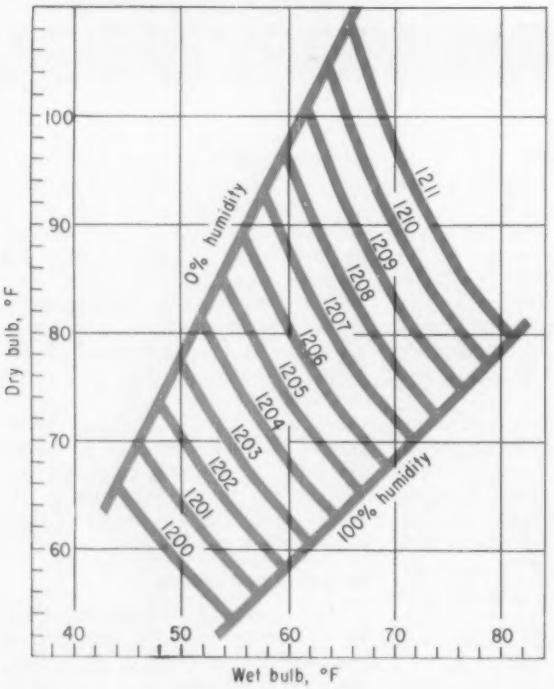
...Coating selection

FULL RANGE



5..Coating selection

NORMAL WORKING RANGE



other type of spray painting—surfaces should be clean and smooth, and free of grease or oil.

With Stresscoat, however, carbon disulfide is employed as a solvent. The vaporized solvent is not only highly explosive—it is poisonous. Therefore, coat the specimen in a spray booth if at all possible. A booth with a down draft is best because carbon disulfide vapor is heavy. According to one authority, (see "Dangerous Properties of Industrial Materials", N I Sax, Reinhold Publishing Co, New York, 1957), the continued breathing of more than 20 parts per million can be a serious health hazard. In addition, the autoignition temperature of vaporized carbon disulfide is approximately 260 F —therefore, the spray from the gun should not be permitted to strike heated surfaces. **An electric light bulb is known to have caused a fire during a coating operation.** If a spray booth is unavailable, spraying can be done outside, using the gas mask provided with the Stresscoat kit.

Before coating, apply a reflecting undercoating of aluminum paint to provide a uniform background for observing the cracks. It is recommended that only the aluminum undercoating provided by the manufacturer be employed because it is so formulated that it will not bleed out when the indicating coating is applied. Dry the undercoating for about 15 min. before the brittle coating is applied.

Although any good commercial spray gun can be used, the gravity-feed gun provided with the kit is usually convenient for general application because it can be cleaned easily. However, for small items or for locations difficult to spray, a small artist's air brush works successfully. The shop's air supply is satisfactory for spraying purposes provided no oil or water droplets are entrained. If the compressor with the kit is employed, use also the drying and filtering unit for both the undercoating and indicating coatings when the weather is humid or rainy. Otherwise, excess moisture will be trapped in the coatings and affect their quality.

Some practice is required for good-quality application. If the gun is held too close to the object, the coating will run. If the gun is too far away, dry power will be blown into the coating, producing a dull, nontransparent effect. The solvent will occasionally evaporate from the cans of coating; hence, a small amount of thinner may be necessary. Otherwise, the gun will not function properly and coating will be of very poor quality.

Sometimes the dry powdered resin

formed from the over-spray collects on tacky, newly painted portions of the structure. Removing this powder by brushing will usually scratch the coating. To improve appearance, a final spray of the affected portions with a diluted coating mixture will sometimes dissolve the surface dust coat. Avoid dissolving the base coating and producing runs.

A coating of 0.003 to 0.005 in. is usually in the best thickness range. Optimum thickness can be determined visually with a little practice. If the coating has a light lemon color, it usually is too thin; if it has a deep orange coating, it is too heavy. A medium-orange color is generally acceptable. Although sensitivity of the coatings is not greatly affected by thickness, a uniform coating is, of course, to be preferred.

A coating with many small subsurface bubbles is better than a solid coating. Cracks tend to progress from bubble to bubble, thus avoiding formation of the long running cracks which otherwise develop. Long running cracks may not provide the close definition of the stress areas desired. Because these bubbles usually develop only in sprayed coatings, the spraying technique is better than other techniques, such as brushing.

After applying the coating, dry the specimen or structure at a temperature above the temperature at which the coating is to be tested. However, satisfactory results can be obtained when the coating is dried in the room in which the test is to be performed, provided the temperature is not allowed to drop to the level at which craze cracking of the coating will occur. When coating a large structure outdoors, and a drop in temperature is expected, cover the structure with a tarpaulin and use space heaters to maintain the temperature at a level near or slightly above the selected testing level. Do not expose the coating to a drop in temperature for even a short time. Opening an outside door during the winter can cause difficulties—one blast of cold air can destroy a day's careful work.

To accelerate drying of the coating, try temperatures up to 140 F. A suggested drying procedure is to place the coating part in an oven for 2 hr at 100 F. However, prior to the accelerated drying period, keep the coating at room temperature for approximately ½ hr.

Crack sensitivity

For quantitative analysis, you must determine the crack sensitivity or calibration of the coating. The Stresscoat kit contains equipment designed to simplify the procedures: a set of six calibration bars, a loading jig, and a calibration scale. The coating applied to the test specimen is also applied to one or more calibration bars. The bars are then placed alongside the structure and are exposed to the same drying conditions.

In tension strain tests, place one of the coated calibration bars in the loading jig and load according to the testing schedule. The coating, though brittle, is plastic in behavior, and tends to creep under load. Therefore try to apply the load on the bar at the same rate as the load on the test specimen. If the test is of such a nature that considerable time is required to apply the load, the bar can be loaded in 1 sec, and a correction made for the creep in the coating on the structure, according to the creep-correction chart. This method is preferable for long-time loading because it is difficult to load the calibration bar over a long period. It is best to calibrate the coating at the beginning and at the end of each experiment, using several bars.

When calibrating the coating for compression strains, position the coated bar upside down in the load jig and hold under load for 2 hr. Then, release the load to develop the crack pattern. The crack sensitivity in compression is determined in the same manner as in tension calibration described above.

Tension testing

When making preparations for loading with the resin-base coatings, decide which procedure is most applicable to the experiment. Often only the maximum tension strains are required —although to get a complete analysis, both tension and compression strains should be determined. Frequently it is also necessary to determine the strains under dynamic loading.

For obtaining static tensile stresses, the general test procedure is:

- Apply the load in step fashion and release after each application ("return-to-zero" or "increment" technique).
- Apply the load at a steady rate.

The increment method is quite common and usually preferable because the coatings have a greater crack sensitivity if loaded quickly. After releasing the load, a waiting period equal to three times the loading time is necessary to permit the creep in the coating to recover. This period provides an opportunity for careful inspection of the coating. When this method is used, loads are applied in increments usually not in excess of 25% of the preceding total load.

The second method is preferable if it is inconvenient to load in step fashion. However, crack sensitivity continually decreases during loading and corrections must be made for plastic creep (see chart, Fig 3).

Regardless of the method of loading, it is helpful to trace the boundaries of the crack pattern for given load levels. These boundaries will aid in interpreting the results and in defining the strained areas if photographs are to be made.

Compression testing

The magnitude and orientation of the compression strains is usually necessary for a complete analysis of a structure. However, Stresscoat cracks only under tension strains, and it is necessary to change the loading procedure to take advantage of the plastic-creep characteristic of the material (the creep characteristic is a disadvantage in some respects, but an aid for measuring compression strains). Either of these procedures can be used:

1. Load the structure under a static load for approximately 2 hr. During this time the coating will relax to an unstrained state. Then, to develop cracks, release the load by increments. After each increment, return to full load for three times the unloaded period. If the load is released suddenly, the crack sensitivity will approach the tension value because compression creep is prevented. Correct for creep for slower release of load.

2. Load the test structure before coating. Then, upon release of load, cracks will appear where compression strains existed.

Dynamic testing

When static testing conditions may not satisfactorily duplicate conditions of loading in service, loads can be applied dynamically and the crack pattern observed under a stroboscope light to obtain quantitative data. If this technique is inconvenient, employ coatings of various crack sensitivities to obtain strain indications under varying dynamic loads. This latter technique is also recommended when only a single application of load is possible. Under these circumstances, find areas of interest which are subjected to the same strain field and intensity during loading. An example might be the spokes or portions of the rim of a wheel. They could be coated with selected coatings having sensitivities in the ranges of the anticipated strains.

6..Gun for spraying...

... ELECTRIFIED PARTICLES TO ACCENTUATE THE CRACK PATTERN.

TABLE II... Pipe-branch analysis

Pressure, psi	Crack Location by Area	Apparent Strain, (micro in./in.) at 300 psi	Apparent Stress psi, at 300 psi
50	None	–	–
100	None	–	–
150	A,B	2000	20,000
200	C,D added – A,B grow	1500	15,000
250	A,B,C,D grow	–	–
300	A,B,C,D grow	–	–

Because the cracks of the less sensitive coatings may close when the dynamic load is released, before loading cover the surface of the indicating coating with the penetrant intended for use with electrostatic powder. Then, during the dynamic test, the penetrant will flow into the cracks as they form.

With such a dye penetrant, only one load application can be made because the dye makes the coating useless for further testing. However, with electrostatic powder, the structure may be tested under increasing loads until the desired crack pattern develops.

Crack patterns

You must have adequate lighting to observe crack patterns. Any uniform white light is good. The cracks are fractures in the transparent coating, and the light will be reflected from the fractured surfaces and produce bright lines. For maximum reflection the light should be directed tangent to the surface of the coating. Excellent bright-line photographs can be made of crack patterns with only a minimum of experience. Some cracks tend to close up and consequently will not reflect light; therefore, either photograph the coating under load or employ another means for revealing the closed-up cracks.

To reveal such cracks, use the dye etchant provided with the Stresscoat kit. This penetrates into the cracks, making them visible. Before the excess dye dries, remove it from the surface of the coating by first sponging the surface of the coating with a soft cloth dipped in an etchant emulsifier, then cleaning by more sponging with clear water at the same temperature as the test structure. Don't use cold water because it can completely craze the coating. Although the crack pattern can be preserved in this way, the coating has been rendered useless for further testing.

To see the cracks and be able to continue the loading, use the gun, a special penetrant and electrostatic dust (available from Magnaflux Corp) Fig 6. Apply the penetrant to the surface of the coating prior to loading —then as the cracks develop, the penetrant enters the cracks. After the surface of the coating is dry, blow the electrostatic powder over the crack pattern. The dust becomes electrostatically charged when blown through the hard-rubber nozzle and, wherever cracks are located, the positively charged dust particles are attracted to the negative ions in the penetrant. The dust particles accumulate over the crack.

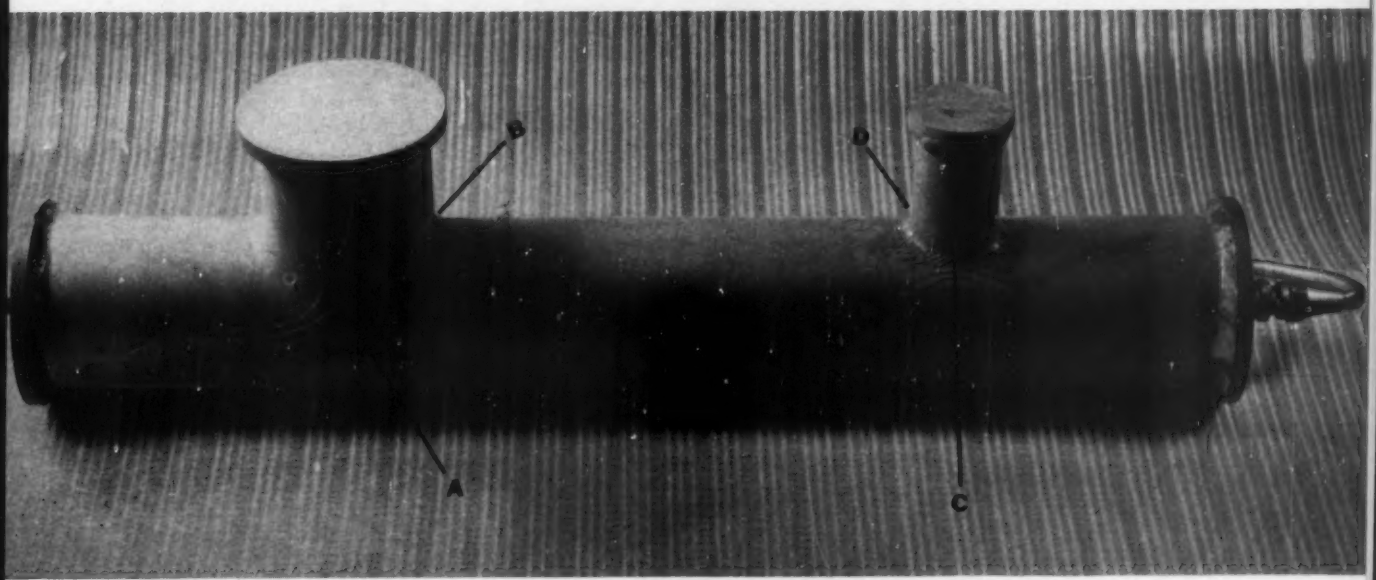
Advantage of this method is that the crack pattern can be developed as the test progresses without need to stop the test. A special preparation is provided to "fix" the dust pattern if desired.

For a specific problem

We recently applied Stresscoat to the analysis of strain concentration in a pressurized pipe system in which branch connections were to be made. Details of the application are given here to provide a working example of the technique. The ratio of pipe diameter to the branches was 1:1 and 2:1, respectively (Fig 7). The pipe was of 6061-T6 aluminum (with a modulus of 10×10^6 psi). Its OD was 2.50 in., its wall thickness, 0.065 in. Wall thicknesses of the pipe and branches were the same.

The test was conducted in a room held at 76 F ± 2 deg, but without control of the humidity. The first step was to select the coating. The sling psychrometer was used in making the selection. The wet bulb reading

7..Crack pattern...



. . . DEVELOPED DURING HYDROSTATIC TEST ON PIPE-BRANCH CONNECTIONS.

was 62 F and the dry bulb reading 76 F. According to Fig 5, coating 1206 should provide a crack sensitivity of 0.008 in. per in. strain.

The coating was applied in a thickness range of about 0.004 to 0.005 in. Calibration bars were also coated and cured along with the pipe. Pipe and bars were dried at room temperature.

The pipe was pressurized with oil and the "return to zero" technique was employed because the load could be applied in a relatively short time. Results of the tests are shown in Table II. (Crack locations A, B, C and D, referred to in Table II, are shown in Fig 7.) At beginning of the test, a calibration bar was loaded in 10 sec. The threshold crack sensitivity was shown to be approximately 0.0010 in. per in. strain. This coating, therefore, was less sensitive than predicted by the chart. However, the chart is set up for 1-sec load application and, in addition, the humidity conditions changed during the test. The pipe was then brought to selected pressure levels in 10-sec intervals. Pressure increments were 50 psi, and the cracks were inspected between each increment.

The first cracks appeared at 150-psi pressure at points A and B in the 1:1 branch at two locations simultaneously. Similarly located cracks occurred in the 2:1 connection at 200-psi pressure; they also occurred simultaneously. When the pressure in the pipe reached 300 psi, the maximum circumferential strain was approximately 2000 microin. per in. strain in the 1:1 branch, and 1500 microin. per in. in the 2:1 branch.

To check on the crack sensitivity of the coating as determined from the calibration bar, Tatnall Metalfilm strain gages (type C 12-141) were cemented to the main section of the pipe approximately 1 dia from the branches. The first cracks occurred at a strain of 1060 microin. per in. in the circumferential direction. This agreed reasonably well with the nominal 1000-microin.-per-in. strain sensitivity predicted with the calibration bar.

Employing the experimental measurements as determined by the strain gages and the Stresscoat, the calculated concentration of the strain in the 1:1 connection was 5.3 while the calculated concentration in the 2:1 connection was 3.2. This indicated the areas of highest strain (at the 1:1 connection) and the comparative strength between the two connections. This was a basis for strengthening the connections.

THE MICRO TECHNIQUE

Ordinary brittle-coating techniques are inadequate for very thin or miniature parts because the usual 0.004- to 0.005-in. thick coatings might sometimes be several times the thickness of the metal being studied. Strain gages, although quite small today, are still not small enough for many parts such as a tiny watch gear. Photoelastic coatings, though otherwise excellent, lose their sensitivity when made ultrathin. However, at Battelle, it was believed that brittle coatings could be adapted if the coatings could be applied thin enough and if the accessory equipment could be miniaturized to meet the needs.

Miniaturization

The first step was to miniaturize the equipment. Calibration bars were made from "blued" commercial spring stock ⅜ in. wide by 0.050 in. thick. Thus, a practically inexhaustible supply of calibration bars was made available without special machining

and heat treating. The loading jig was miniaturized so that it could be placed under a microscope stage. The calibration bar was incorporated into the design of the loading jig so that the bar would not have to be removed to check the strain sensitivity. Results are shown in Fig 8.

The next most important item was the spraying equipment. To apply the coating in the thickness range of 0.0005 to 0.001 in., a fine spray was helpful. A small spray gun may be best if adjustments are available for both air and lacquer. However, the spray gun supplied in the Stresscoat kit was found to be satisfactory if the air pressure is carefully controlled.

Selecting the coating

In selecting the coating to be used with Battelle's new technique, keep in mind that extremely thin coatings are not as sensitive as coatings of the usual recommended thicknesses. Therefore select a coating four or six numbers above that recommended by the charts in Fig 4 and 5. Thus, if No. 1206 is the normal choice, No. 1210 or No. 1211 should be employed. Each particular application will require more or less sensitivity depending upon the test conditions. For example, it was found that 0.0005-in.-thick coatings of No. 1206 have a sensitivity of about 1500 microin. per in. strain at a temperature of 76 F. If the No. 1210 coating were selected instead of the indicated No. 1206, the sensitivity would be increased from 1500 to 1000 microin. per in. strain.

The most critical operations are the proper thinning of the coating and the spraying. Various coating concentrations were studied; the results varied according to the air pressure and nozzle adjustments. In general, a dilution of 5:1 was found to be satisfactory in applying coatings approximately 0.0005 to 0.001 in. thick.

The coatings applied did not have bubbles in them and were entirely transparent. One problem was in regulating the coating thickness because it is difficult to see the coating.

After the spraying operation is complete, cure the coating at 10 to 15 F above the room temperature. This will reduce or eliminate craze cracking. Calibration bars should be coated along with the part under study.

Application to a problem

We employed the technique to locate the tension and compression areas in a 0.0025-in.-thick beryllium copper diaphragm. Ordinary experimental stress-analysis techniques were not suitable. A 0.0005-in.-thick coating of No. 1210 coating diluted 5 to 1 with carbon disulfide was applied. It was dried at 20 F above room temperature for ½ hr and then allowed to come to room temperature slowly. Calibration bars were loaded in about 10 sec, and the sensitivity was found to be about 1000 microin. per in. strain.

Pressure was applied to the diaphragm in small increments to a total of 50 psi, the maximum selected pressure. Inner circumferential cracks appeared in the diaphragm. The diaphragm was then subjected to a vacuum of about 5 in. of mercury absolute pressure. Outer circumferential cracks then developed. The uncracked area between the inner and outer cracks was presumed to be the transition area between tension and compression strains.

Although this micro-Stresscoat technique has been applied only to the study of membranes and diaphragms, it should find many other applications in the stress analysis of miniature parts such as small switches, gears, bearings, and housings. The sensitivity of the coatings in ultrathin coats is low, but it may be controlled by conducting the experiment under cold water. When such experiments are conducted, the calibration bars and the test specimen should both be immersed. In this way, greater sensitivity can be attained. Thus, the number of applications can be increased.

GLASS-BASE COATINGS

Stresscoat All-Temp is formulated in six different grades which have nominal crack sensitivities varying from 200 to 2000 microin. per in. strain. The actual strain sensitivity, however, depends, as in the case of resin-base coatings, not only upon the type of coating and the testing temperature, but also on the mean coefficient of thermal expansion of the material to which the glaze is applied. (see chart in Fig 10). The coating can be applied to carbon steels, chromium-nickel steels, chromium, titanium, and cast iron.

The limiting factor, the temperature necessary to fuse or glaze the coating, is from 950 to 1050 F. The time required is usually just long enough to bring the coatings to the glazing temperature. Although these temperatures may be prohibitive in many cases, the time at temperature is short, and the amount of oxidation may not be serious, depending upon the material. The uncoated machined surfaces of carbon steels darken only slightly, and the oxide coating formed is very thin—therefore, surface protection for uncoated machined surfaces is usually not necessary.

Although glass-type glazes are brittle and, therefore, useful for stress-analysis work, the problem has been to obtain frits having relatively low glazing temperatures and, in addition, controlled crack sensitivities. Unlike the resin-type coatings, the glaze coatings do not creep and adjust themselves to materials having varying coefficients of expansion. Therefore, to select a suitable coating for a given application, consider the thermal coefficient of expansion of the material being analyzed and the strain level at which it is wished to have cracks occur. After the glaze and the metal have cooled after firing, the glaze will be in a state of compression or of tension, depending on differences in the coefficients of expansion of the two materials.

For example, if the metal to be coated has a coefficient of thermal expansion greater than that of the glaze, upon cooling the glaze will be under residual compression stress. This residual compression stress tends to decrease the crack sensitivity. However, upon heating, crack sensitivity increases until the temperature reaches about 600 F. In this temperature region, the sensitivities of all the coatings tend to decrease as the glazes begin to soften under the heat and selection of a coating will depend upon the coefficient of expansion of the material to be tested, the desired strain crack sensitivity, and the temperature at which the test is to be conducted.

Applying the coating

The surface of the material should be clean and smooth, though not polished. A grit-blasted surface is quite satisfactory, although too much surface roughness is not desirable because it will interfere with the detection of cracks. With rough castings, it is often necessary to grind the surface and to preheat the casting above the glazing temperature. This tends to minimize the evolution of gas during the glazing. Excessive gas evolution produces an unsatisfactory porous coating.

The glaze should be sprayed in a commercial spray booth because both the frits and the liquid vehicle are toxic. Use a gas mask if a booth is unavailable. Again, as with a resin-base material, the liquid vehicle is inflammable and care should be exercised to avoid explosions.

The gravity-feed spray gun provided with the kit can be employed to apply the coating. The frits are actually suspensions of powders in a

hydrocarbon vehicle and there is a tendency for the suspended powders to settle out. However, if a circulating system is used in line with the spray gun, Fig 9, settling is largely avoided. The actual application of the coating requires some practice. Unlike resin-base coatings, Stresscoat All-Temp is not transparent as applied, and it is more difficult to determine the thickness of the unglazed coating. Coatings 0.003 to 0.005 in. thick are usually satisfactory. Check for proper thickness with a pointed object at non-critical locations. Apply the coating with enough vehicle to give it a wet or shining appearance. If an area is allowed to dry and an extra coat is applied over it, blistering will result; therefore coat only small areas at a time.

Glazing the coating

Glaze the coating in an electric furnace if possible—a gas-fired muffle furnace will be satisfactory if an oxidizing atmosphere is maintained. Avoid over-firing. For large parts, attach thermocouples internally and externally, and bring the structure up to 850 F throughout. After the part has become uniformly heated, increase the temperature to the glazing point. This procedure minimizes the time that some parts of the structure have to be at the glazing temperature more than others. If possible, watch the part in the furnace. Glazing is accomplished when the dull gray turns to a shining gray-black. Now, reduce the temperature of the part as quickly as possible, but avoid setting up large thermal strains during cooling. Care is required in large structures or where there is a rapid change in section after the part is cooled. Check also the coating for quality and imperfections. If the coating is a dull, yellowish brown, it is over-fired and should be removed by sandblasting, and the part recoated. If the coating is a glassy red to light yellow, it is probably satisfactory for testing.

Conducting the test

Unlike the resin-base materials, the glazed coating requires no special protection from oil, water, or reasonable mechanical handling. Also, because glazed coatings do not creep at normal operating temperatures, the testing techniques are less exacting than those for Stresscoat. All that is necessary is to apply loads according to a predetermined schedule and check for cracks using the electrostatic dust technique.

An example of the use of the glazed coating at Battelle is the determination

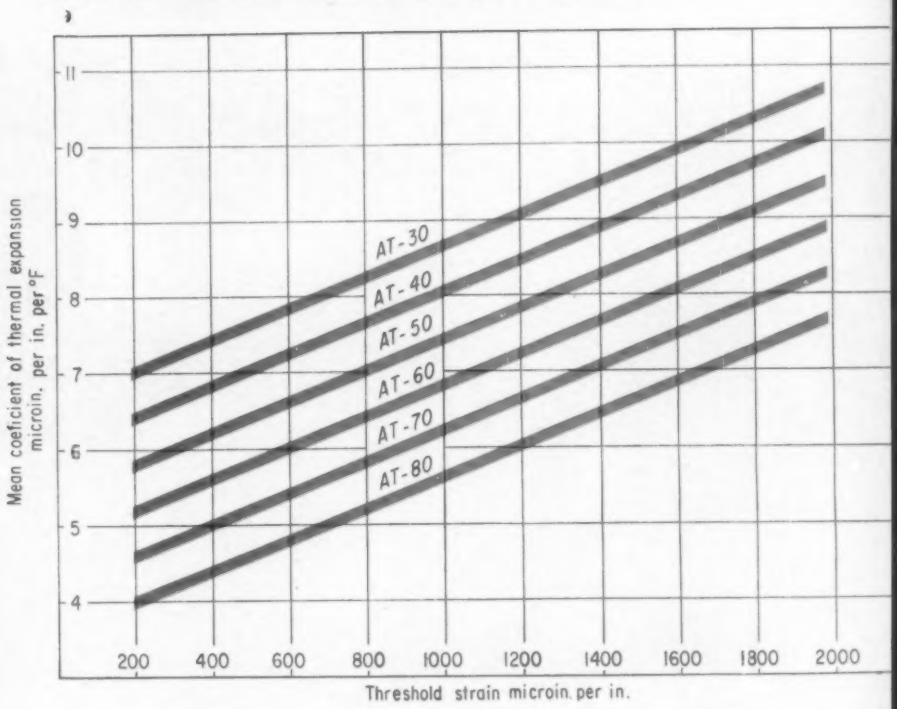
8..Miniaturized...

. . . loading jig developed at Battelle, and commercial artist type spray gun.

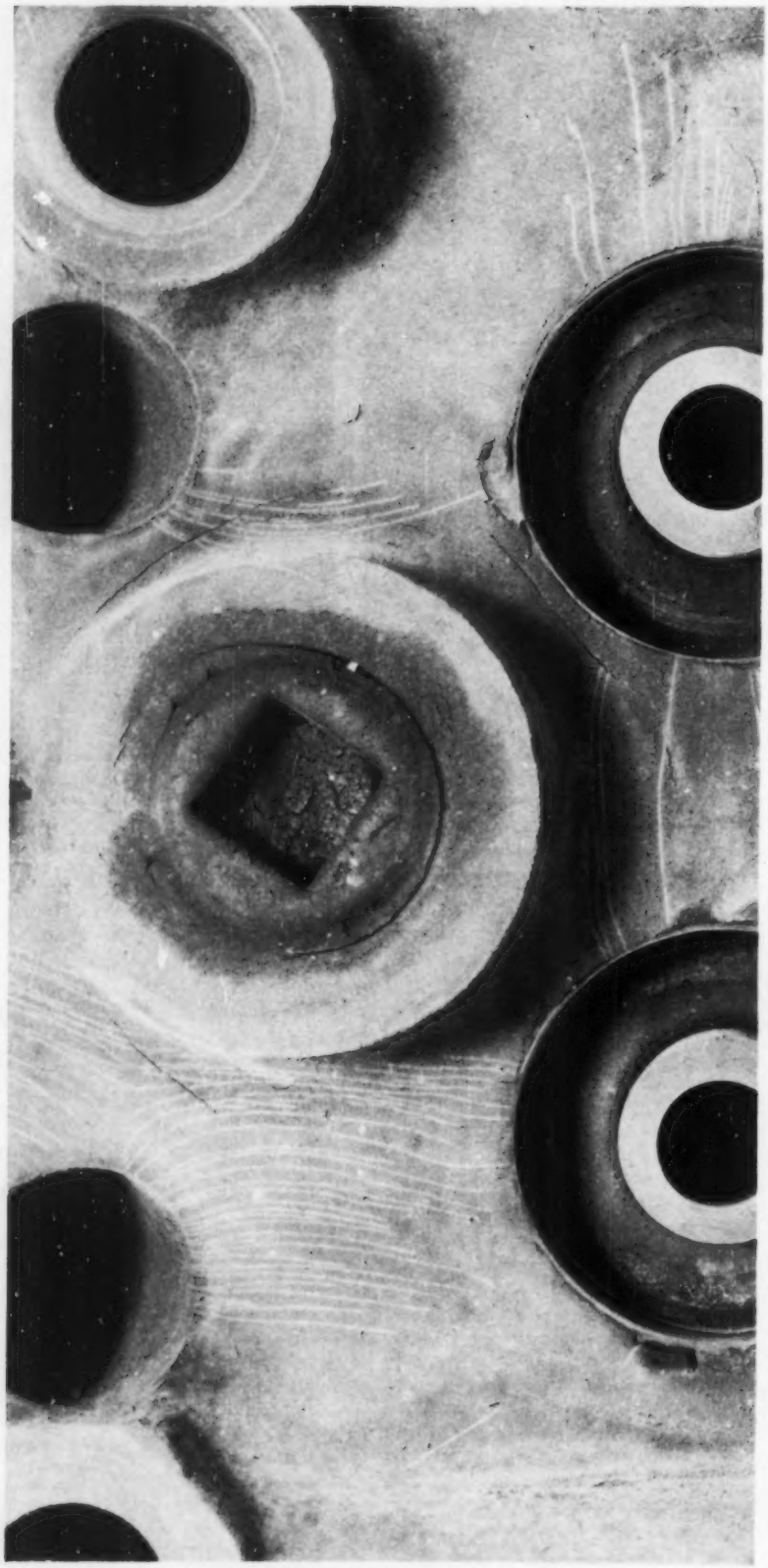
9..Recirculating...

. . . system developed at Battelle for spraying All-Temp—a glass-base coating.

10..Stresscoat all-temp selection



11..Pattern...



. . . IN ALL-TEMP COATING OF ENGINE HEAD DURING CYCLING TEST.

of the operational stresses in an experimental internal-combustion engine head, Fig 11. The tested material, being cast iron, had a thermal coefficient of expansion of 6 x 10^6 in./in./F. After preliminary experiments with several coatings of different sensitivities, we decided on a coating with a crack sensitivity of 800 microin. per in. strain because it was considered desirable not to exceed this strain level in the head. Some areas were stressed beyond this level.

The head was then coated and glazed according to the new procedure described for castings of this type. After glazing, the head was installed on the engine and the engine run through its test cycle. The head was removed and examined for cracks using the electrostatic dusting procedure. The dusting technique revealed that cracks had occurred around holes or stress raisers, particularly where the reinforcing bosses were omitted. The cracks indicated that the stresses had exceeded the maximum level considered desirable, and located weak points for further study by strain gages.

For **reprint** of above article, just check 640 on one of the Reader Service cards found in this issue.

EDITOR'S NOTE: This is the second of a series of articles by the staff of Battelle Memorial Institute covering today's experimental stress analysis techniques. The first, "Which Type of Stress-analysis Method?", Oct 16, p 90, compared the seven main categories—brittle coatings, strain gages, photoelasticity, grid systems, X-ray defraction, acoustoelasticity, extensometers—and gave selection tables for finding best candidates.

Coming next is a comprehensive article on strain gages, covering basic types and recent developments, methods of attaching gages, measurements and calculations, and special transducers.

For more information on stresses in cylindrical blocks and pressure vessels see:

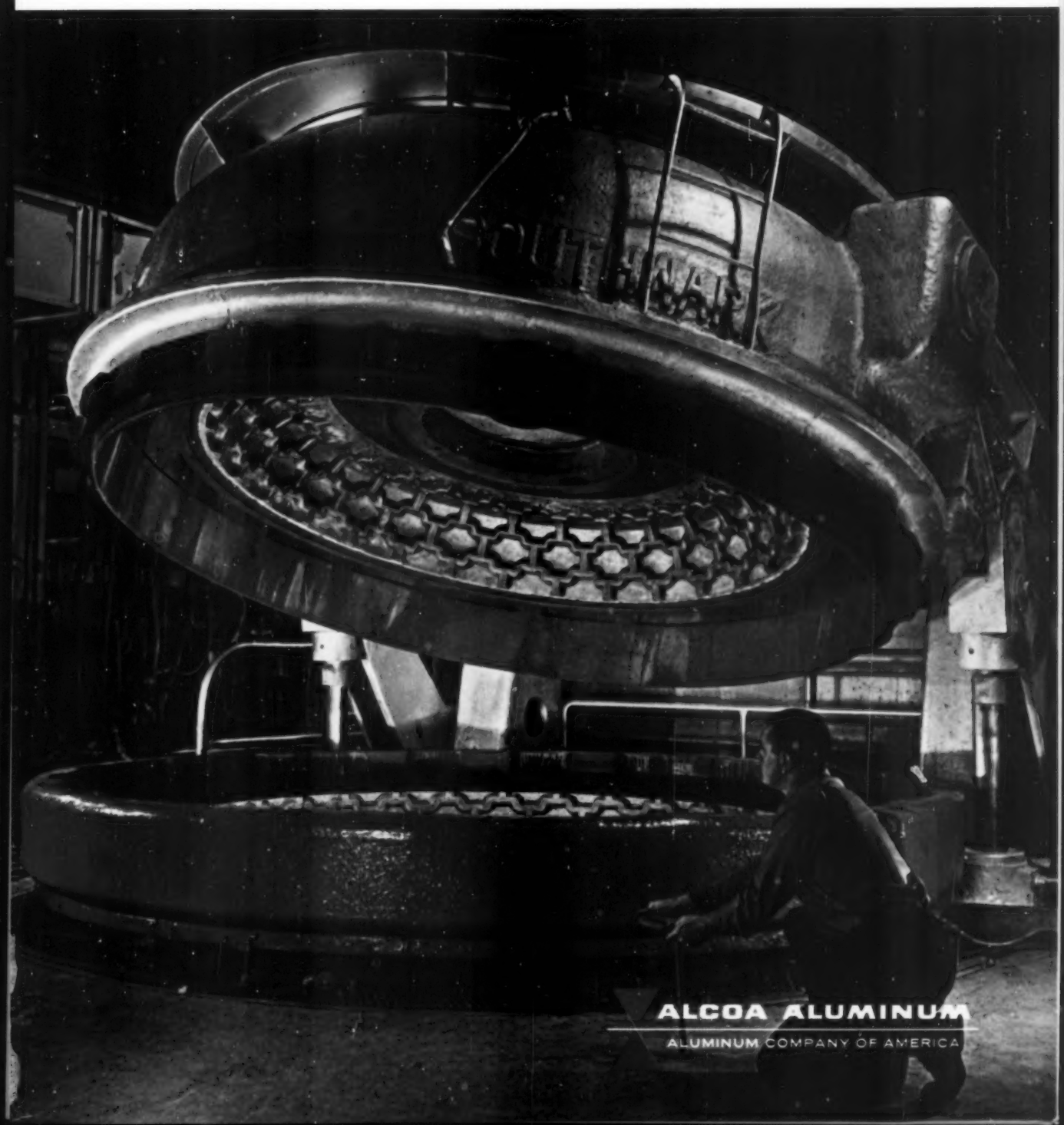
Maximum Stress in Cylindrical Short Blocks, Jan 23 '61, p 63–The article gives charts to analyze whether a block can stand both tension and compression, or only one–regardless of the location of the load–and gives equations you need to determine maximum stress.

Three Nomographs Aid in Designing Pressure Vessels, Nov 14 '60, p 78–For finding wall thickness, hoop stress and pressure limit.

—Nicholas Chironis

CIRCLE 73 ON READER SERVICE CARD→

When superhard-finished aluminum shows no wear in six years . . .



When superhard-finished aluminum shows no wear in six years . . . . . .

that's Alcoa Total Ability at work!

Molding earth-mover tires takes 1,000 psi minimum at 200 to 325°F for as long as 12 hours straight. Six years ago, the world's largest tire tread mold insert, 36.00 x 41—an *aluminum* casting—was hard-coated by the Alcoa* Alumilite* process. No wear has been found and none is expected.

Originated and developed by Alcoa research, the Alumilite process gives aluminum a "file-hard," thick, dense coating. Formerly, passenger-car tire molds wore past tolerances in just 30 days. With Alcoa's Alumilite Hard Coating, their service life is indefinite. Other coatings hard enough to protect as well cost about *three times* as much.

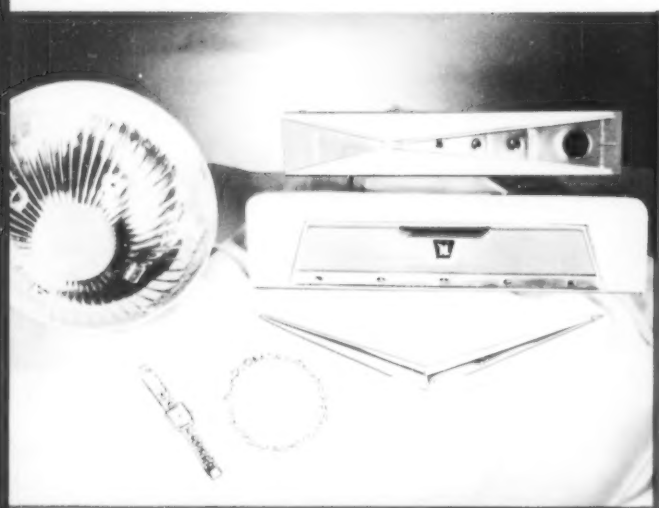
At work or on display, aluminum takes a thousand finishes. Electrochemical processes like Alumilite guard it from weather and wear. The rainbow's colors grace Alcoa Aluminum through surface treatment or finishing. It's textured a hundred ways. A 48-page, full-color booklet, *Finishes for Alcoa Aluminum*, is available. Send for your free copy.

Shapes of aluminum in endless variety also come from Alcoa's forges, foundries, rolling mills and extrusion presses. Truly, imagination's the only limit when *Alcoa Total Ability* works aluminum for you. Learn the difference it can make in *your* products (and profits!). Call your nearby Alcoa sales office, or write: Aluminum Company of America, 857-L Alcoa Building, Pittsburgh 19, Pa.

*Trade Name of Aluminum Company of America

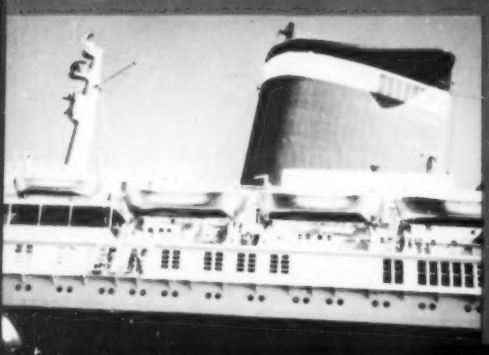
ALCOA ALUMINUM

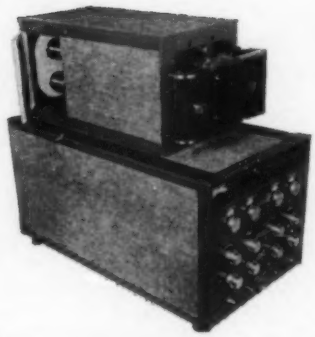
ALUMINUM COMPANY OF AMERICA

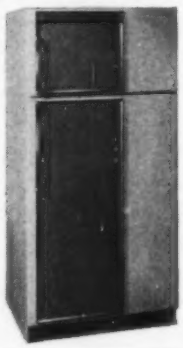


Alcoa Aluminum—the metal with a limitless number of applications—can be finished by every mechanical, chemical and electrochemical method used on other metals . . . and *more!*

You can polish it, blast it, buff it, burnish it, hone it, emboss it, coin it, peen it, etch it, bright-dip it, anodize it, electrobright-dip it, paint it, lacquer it, enamel it, porcelain-enamel it, laminate it, metalize it, satin-finish it.







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Take the matter of costs. Since Masland Duran Clad is an *integral* finish, you can work with pre-finished parts. That means you can often do away with the need for baking and spraying. No new processing equipment needed, either. This colorful, handsomely designed vinyl can be permanently laminated to metal . . . and cut, crimped, drilled or deep drawn without distortion or marring. As for saleability . . . there isn't anything that excels color-bright, easy-to-clean Clad for attracting immediate and favorable attention to your product. For samples, mail this coupon.

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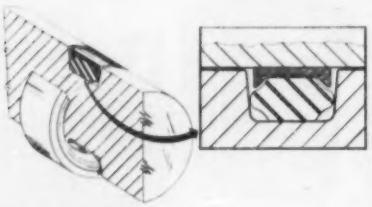

Teflon-capped ring seal . . .
is said to be self-centering and to resist "tipping" and spiral failure in groove, assuring positive seal at pressures up to 3000 psi. Ring's configuration provides "shoulders", on which Teflon component rests. Designed for use without backup rings and may be installed in standard MIL-P-5514D O-ring grooves. **W S Shamban & Co, 11617 W Jefferson Blvd, Culver City, Calif.**

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Indexing and locking device . . .
provides adjustment of control linkages. Consists of two investment-cast serrated washers, with each notch representing 0.001 in linear adjustment. Mechanic need only turn device the required number of notches to obtain desired setting. Conforms to NAS spec 1193. Available sizes range from 0.260 in. ID and 0.44 in. OD to 0.265 in. ID and 2.88 in. OD. **Arwood Corp, 321 W 44 St., New York.**

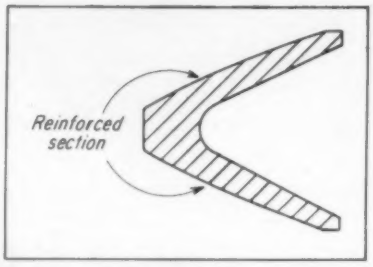
Circle 301 on Reader Service Card

Set screw has knurled cup point
and a thread form with rounded root. In simulated applications with vibration loadings, set screw remained tight at least 2-½ times longer than other knurled cup and plain cup points both with and without plastic locking devices. Smoothly radiused thread root is said to distribute stresses to permit tightening torques as much as 40% higher than comparable fastenings. Available from stock at same price as this manufacturer's standard line of hexagon set screws, diameter sizes #4 though 1 in. **Standard Pressed Steel Co, Jenkintown, Penna.**

Circle 302 on Reader Service Card

Rate transducer . . .
converts moving weight (can be applied to tachometer measurements of 20 rpm or lower) into electrical signal. Signal, proportional to rate and speed of moving weight, can be fed into computer system to control processes or conveyor equipment through closed loop. Consists of pulser wheel, proximity pick-up coil, integrator rate transducer, range box, and measuring instrument, such as meter, recorder, etc. Output is converted to dc or straight-line voltage through solid state amplifier integrating circuit. **Merrick Scale Mfg Co, 180 Autumn St, Passaic, NJ.**

Circle 303 on Reader Service Card

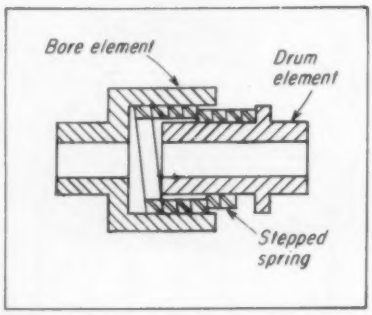


Coated metallic seal . . .
has tapered cross section that acts as reinforcement under pressure. Suitable for pressures from vacuum to 30,000 psi, temperatures of −320F to 2200 F. Available for all standard AN cavities, as well as many irregular sizes and configurations. **Servotronics, Inc, Gruner Road, Buffalo 25, NY.**

Circle 304 on Reader Service Card

Precision rotary switches . . .
are integrally molded units, with conductor sections of conductive plastic molded integrally with insulating plastic base. Terminals are insert-molded in this same base. Since this makes it possible to provide conductive and non-conductive sections of similar coefficients of friction and thermal expansion, stick-slip phenomena are said to be eliminated. Designed for sampling, telemetering, programming, remote control and signaling. If signal-to-noise ratio need not be better than 5:1, and 10,000 revolutions, min, is adequate service life, voltage load can be as high as 30 v, with 300 milliamp current. If 50:1 signal-to-noise ratio is required and longer service life (10 million revolutions, min) is desired, voltage load limit is 30 v with 12 milliamp current. In speed tests, signals were substantially identical at 1000 fpm and 18 fpm. Prices are expected to be in $30 to 1500 range; delivery 4-12 wk. depending on tooling. **Markite Corp, 155 Waverly Pl, New York 14.**

Circle 305 on Reader Service Card

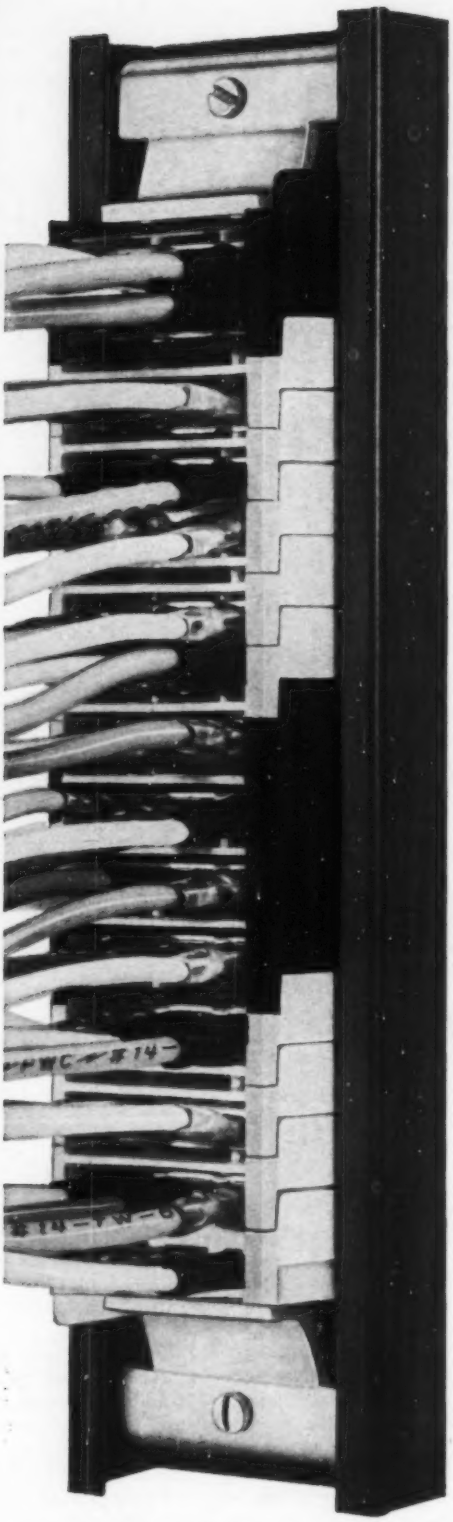


Coupling for continuous slip . . .
serves as a torque limiter as well as a coupling for two coaxial shafts. When load exceeds limit torque, the two shafts rotate relative to each other at full limit torque. Can operate with misalignments up to 0.006 in. between shafts. Limit torque tolerance is ±15%, but can be calibrated to within ±5%. Designed to operate for 1000 hr continuous slip at maximum power dissipation ratings. **Machine Components Corp, 39 Fair Lane, Jericho, NY.**

Circle 306 on Reader Service Card

Gravity-sensing potentiometer . . .
is for use in correcting mechanisms and consists of curved glass tube containing a predetermined amount of electrolytic solution to create air bubble. Motion of air bubble caused by tilting creates variable impedance according to degree of immersion of top electrodes. Advantages over pendulum

continued, on page 84



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THE ONE-TRACK MIND OF TERMI-BLOK*

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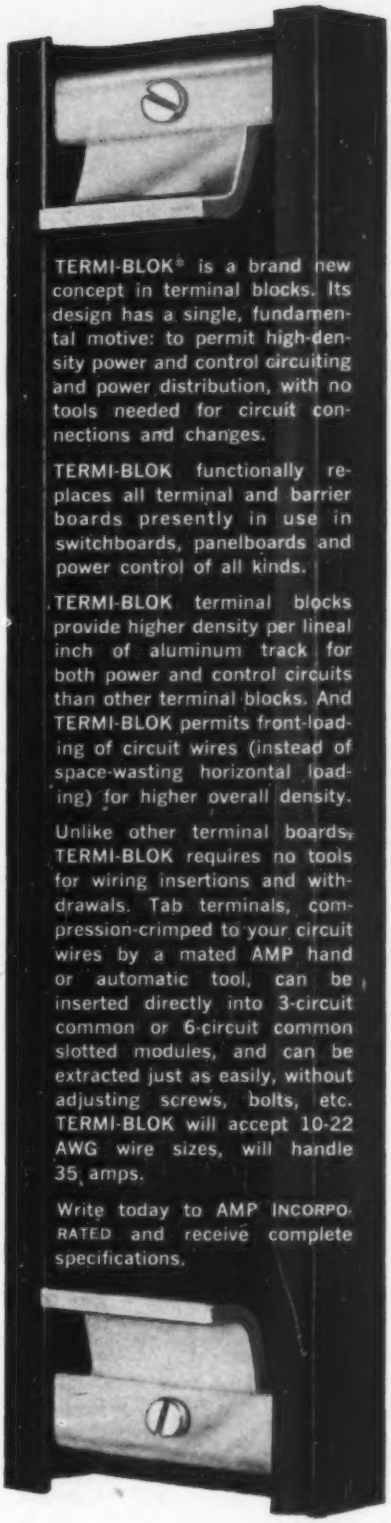

TERMI-BLOK* is a brand new concept in terminal blocks. Its design has a single, fundamental motive: to permit high-density power and control circuiting and power distribution, with no tools needed for circuit connections and changes.

TERMI-BLOK functionally replaces all terminal and barrier boards presently in use in switchboards, panelboards and power control of all kinds.

TERMI-BLOK terminal blocks provide higher density per lineal inch of aluminum track for both power and control circuits than other terminal blocks. And TERMI-BLOK permits front-loading of circuit wires (instead of space-wasting horizontal loading) for higher overall density.

Unlike other terminal boards, TERMI-BLOK requires no tools for wiring insertions and withdrawals. Tab terminals, compression-crimped to your circuit wires by a mated AMP hand or automatic tool, can be inserted directly into 3-circuit common or 6-circuit common slotted modules, and can be extracted just as easily, without adjusting screws, bolts, etc. TERMI-BLOK will accept 10-22 AWG wire sizes, will handle 35 amps.

Write today to AMP INCORPORATED and receive complete specifications.

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GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

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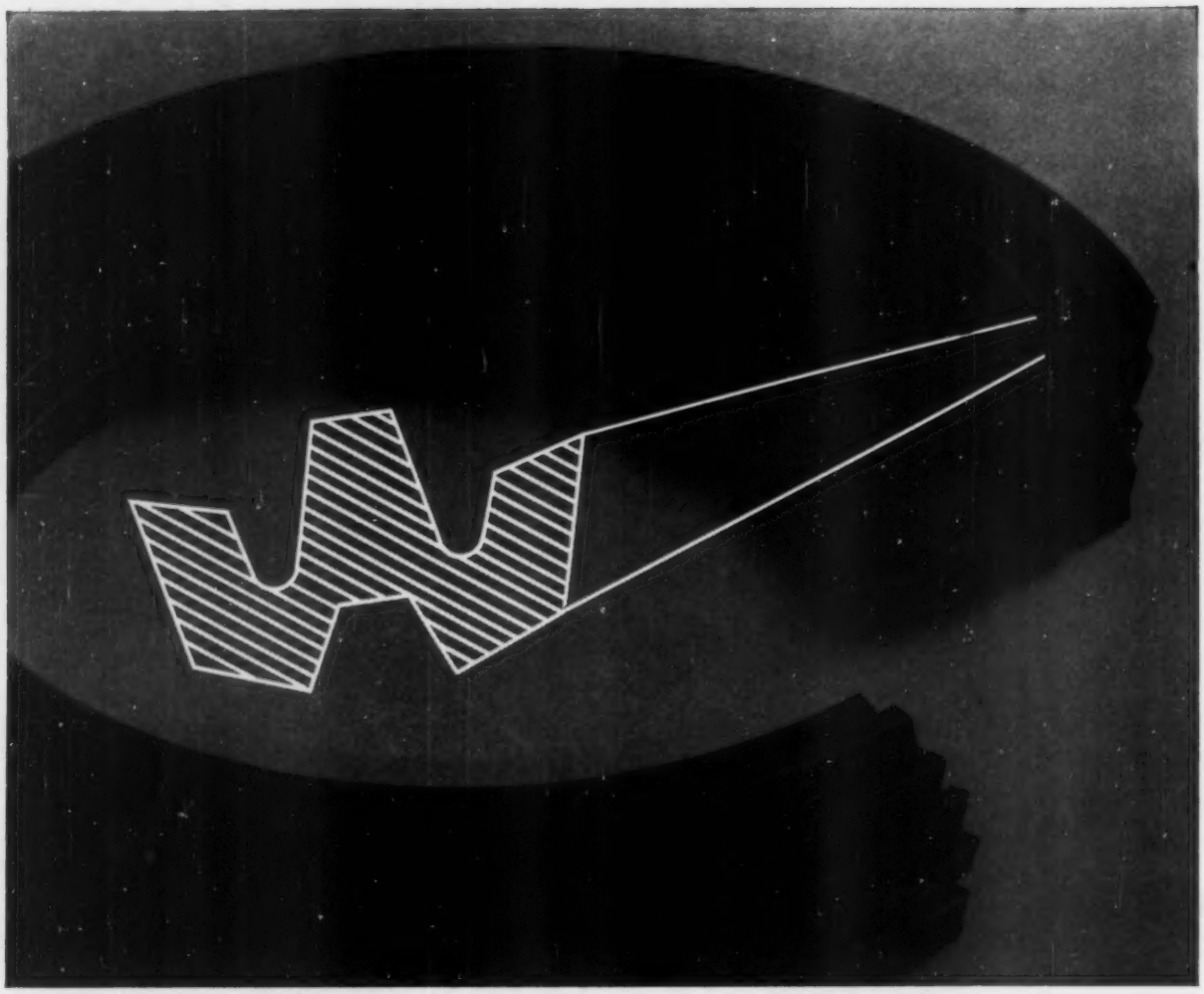

More sealing ability in less space with J-M UNEEPAC®

THIS CROSS-SECTION DESIGN DEMONSTRATES WHY UNEEPAC AFFORDS FULLY AUTOMATIC SEALING, EVEN IN LIMITED SPACE.

J-M Uneepac is designed and engineered to provide a truly automatic lip-packing element for use in applications requiring multiple ring sets in minimum stuffing box depths.

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Easy-to-assemble Uneepac Rings offer peak sealing efficiency at optimum economy. They seal against the most rugged conditions, and give exceptional service life in rod and piston applications. They fit accurately and reduce friction. Uneepac Rings are precision-moulded, skillfully compounded in whatever materials best meet your requirements. A complete range of standard sizes, styles and materials is available for immediate shipment. Or, Johns-Manville will design and custom-make the exact packing you require.

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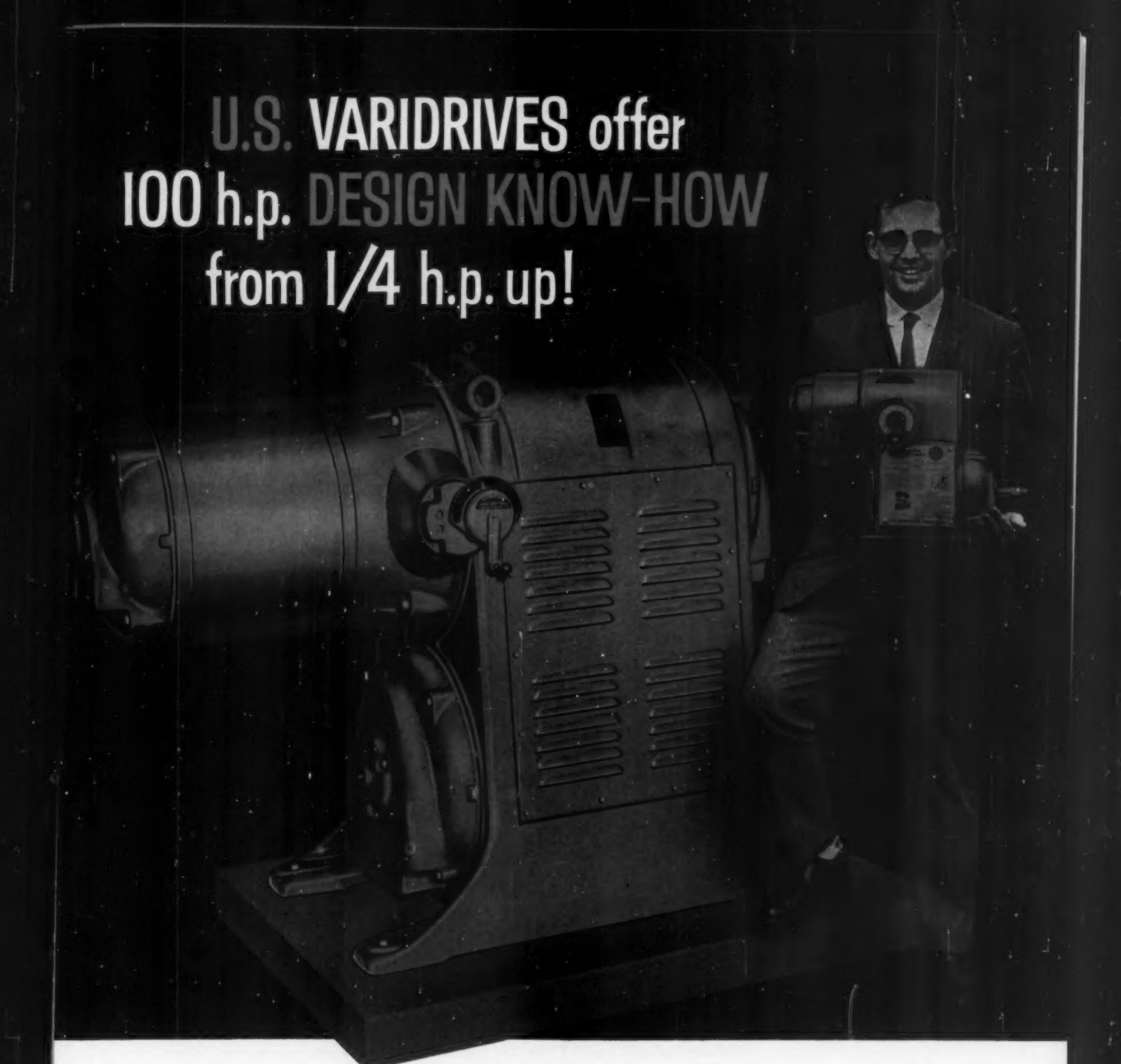

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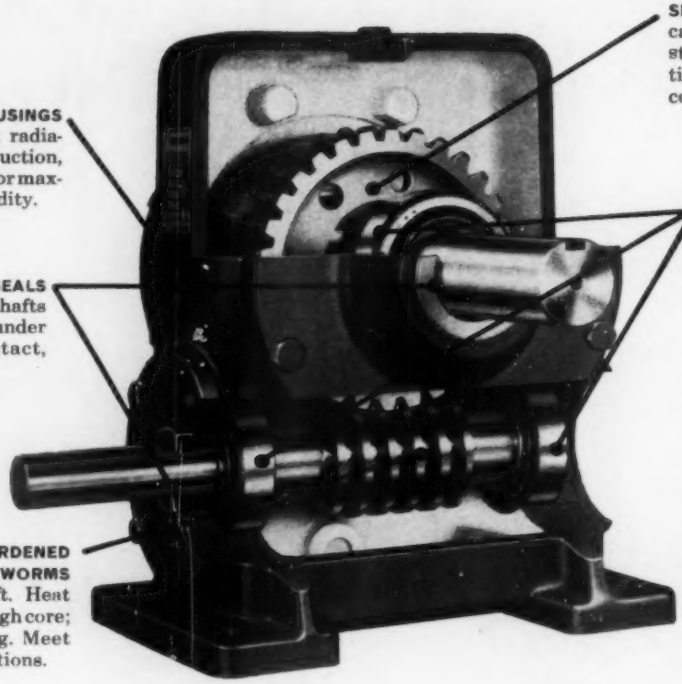
Engineering Data

WINSMITH SPEED REDUCERS

WINSMITH "C" SERIES WORM GEAR SPEED REDUCERS



SPECIAL BRONZE WORM GEARS cast to recommended AGMA standards. Low coefficients of friction and thermal expansion for cooler, more efficient operation.

CAST IRON HOUSINGS designed for high heat radiation. One-piece construction, close-grained gray iron for maximum strength and rigidity.

TAPERED ROLLER BEARINGS for minimum maintenance, long bearing life, permanent shaft alignment. Capacity to handle high radial and thrust loads.

POSITIVE OIL SEALS keep oil in, dirt out. Shafts lapped to micro-finish under seals for uniform contact, longer seal life.

AVAILABLE in single and double reduction models, for intermittent or continuous service. Order from stock with right-angle or parallel shafts, worm on top or bottom, all worm gear or combined worm and helical. All types of special units also available.

CASE-HARDENED GROUND STEEL WORMS cut integral with the shaft. Heat treated for close-grained tough core; carburized before grinding. Meet AGMA long-wear specifications.

- *108 Models*
- *1/100 to 34 H.P.*
- *Ratios 5:1 to 4460:1*
- *Max. Output Torque 142 to 34,767 in. lbs.*

Winsmith "C" Series Reducers are compact units which offer a wide range of horsepower and torque output in minimum space. Their design and construction provides high shock load resistance; maximum thermal capacity without induced cooling; greater overhung load capacity; all moving parts totally enclosed in a dirt-proof housing and lubricated from a central oil bath; and complete interchangeability of major components. These features add up to smooth, trouble-free performance—an extremely low rate of wear—high mechanical efficiency—and greater overall economy per horsepower dollar.

For complete information on Winsmith Speed Reducers, write today or call your nearest Winsmith Representative. You'll find one in every major industrial area, listed in the Yellow Pages. They are technically trained experts who are always ready to help you with any speed reducer problem. For both standard and special power transmission applications, you'll find it pays to standardize on Winsmith.

WINSMITH, INC.

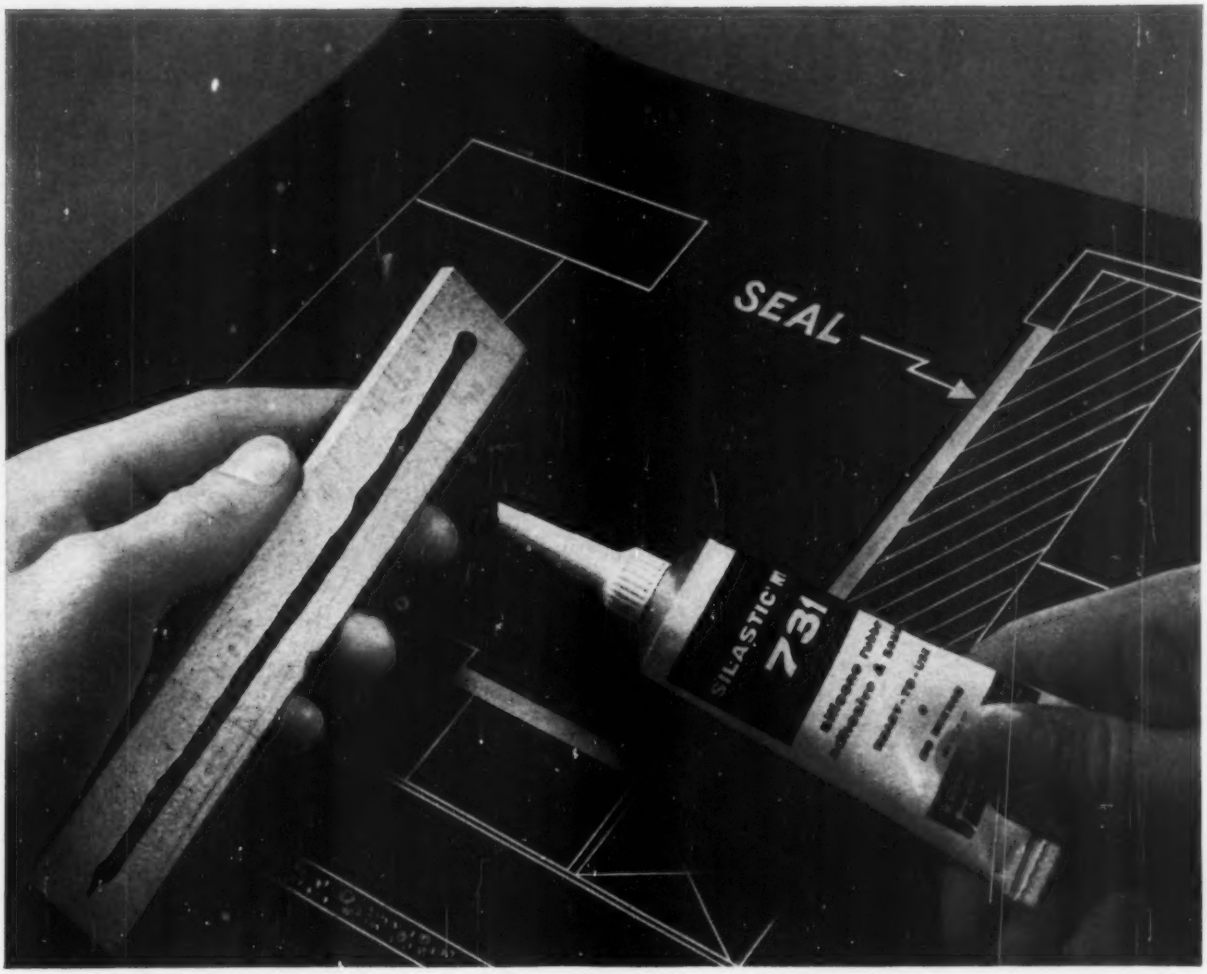
208 Eaton Street, Springville, (Erie County), New York

MEMBER OF AGMA

• • • Winsmith Speed Reducers are made by American craftsmen to meet American design and production standards.

SILICONE NEWS from Dow Corning

Stops leaks permanently



New rubbery adhesive seals out moisture, dust, contaminants

Here's a really durable, silicone rubber sealant that sets-up at room temperature and bonds permanently to most materials, including metals and plastics. Silastic® RTV 731 has the easy-to-use consistency of toothpaste and is supplied ready for application in handy tubes.

Silastic RTV 731 flows out smoothly, clings to most materials, won't sag or slump when applied to vertical surfaces. It quickly sets-up on exposure to air and cures *without heat* to form a tough, flexible silicone rubber seal.

Seals made of Silastic RTV 731 show no loss of either adhesion or flexibility when exposed to low pressure steam, moisture, high humidity or corrosive atmospheres at temperatures ranging from —100 to 500 F. This sealant offers solutions to all types of sealing and bonding problems. Wherever your blueprints call for sealing, it will pay you to look into Silastic RTV 731.

Write for "Greater Versatility with Silastic RTV." Address Dept. 5223a, Dow Corning Corporation, Midland, Michigan.

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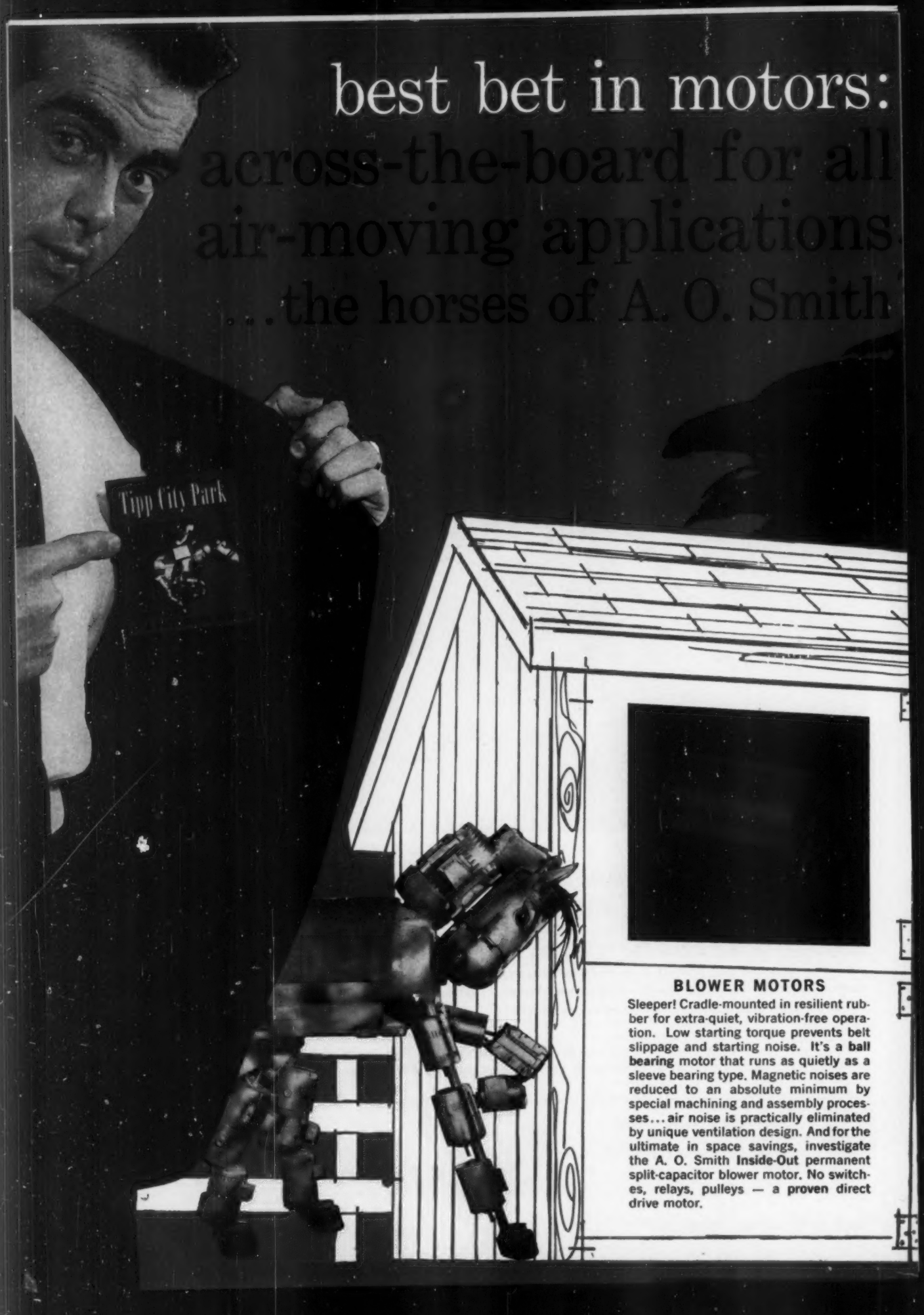
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Sleeper! Cradle-mounted in resilient rubber for extra-quiet, vibration-free operation. Low starting torque prevents belt slippage and starting noise. It's a ball bearing motor that runs as quietly as a sleeve bearing type. Magnetic noises are reduced to an absolute minimum by special machining and assembly processes... air noise is practically eliminated by unique ventilation design. And for the ultimate in space savings, investigate the A. O. Smith Inside-Out permanent split-capacitor blower motor. No switches, relays, pulleys — a proven direct drive motor.

PLAN ACROSS-THE-BOARD — You make your picks from a complete line of air conditioning and heating equipment motors—*blower* types . . . *inside-out* design . . . *hermetics* . . . *integrals* in a wide range of hp plus an exceptional range of modifications.

POWER WITH A PEDIGREE — The right combination of features are bred into each A. O. Smith motor type to deliver top performance for its application. Check the paddock below for individual blood lines.

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ELECTRIC MOTORS

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The workhorse of the A. O. Smith line. These open motors provide that extra amount of moisture protection. And you get quiet operation for critical noise areas along with a power reserve that pulls across adverse operating conditions. Rotors are pressure cast in one operation to provide an indestructible construction. Rotor and shaft assembly are dynamically balanced to minimize vibration. On models up through five hp single-phase, the capacitor is mounted inside the motor housing for space-saving installation, maximum protection and streamline appearance.

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A true thoroughbred! Rotor-stator assemblies are designed specifically for sealed compressors . . . quality-built to provide a reliable source of power for refrigeration or air conditioning, year-in and year-out. They're custom-built and dynamically-balanced for years of dependable, quiet, vibrationless service. What's more, each motor is manufactured under the strictest quality control . . . assembled and tested under controlled atmospheric conditions, ever-free of dirt and dust. Application-engineered in single-phase and polyphase, ¾ to 100 hp.

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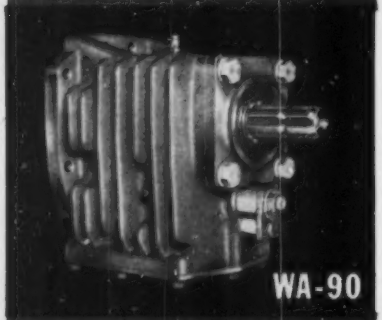

WHEN WARNER HAS A PART IN IT!

This new two-speed power take-off for heavy-duty tractors is typical of the precision assemblies produced at Warner Automotive Division for farm equipment manufacturers.

Simply by changing the output shaft, the farm operator can change his PTO speed from 540 RPM to 1000 RPM —a wonderful convenience in rush seasons. Variations of this principle are being applied to other types of farm implements.

Let Warner Automotive develop mechanical power transmission parts for your specific needs. Our engineering staff is at your service on any problem, without obligation.

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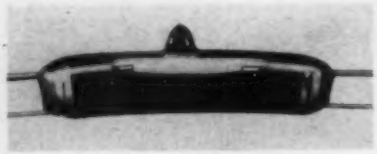
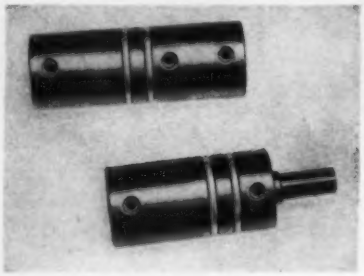


or mercury switch devices are said to be: damping action, because normal viscosity and surface tension of fluid used provides smoother action; proportional output is obtained as horizontal position is approached, permitting closer control. Glass tube illustrated is 1¼ x ⅝ in. dia. **Hamlin, Inc, Lake Mills, Wis.**

Circle 307 on Reader Service Card



Miniature slip clutches . . . for use as overload couplings or where constant torque is required have locking set screw for adjustment of torque transmission through range of zero to 4 in.-lb. Made of oil-impregnated metal powder parts requiring no lubrication. Two types are available: Model K is designed to couple two shafts. Model M has ¼-in. bore on one end and ¼-in. shaft on other. **Precision Specialties, Inc, Pitman, NJ.**

Circle 308 on Reader Service Card

Lamp signals for replacement . . . using two filaments. One filament supplies major portion of light output, the other is less bright and has longer service life. When brighter filament burns out, bulb continues to function, but at noticeably lower candlepower

continued, page 88

◀ Wheel Brake and Swivel Lock Casters

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▲ Wheels of all sizes and types

◀ Extra Heavy-Duty Casters

▶ Dual or Triple Wheel Casters

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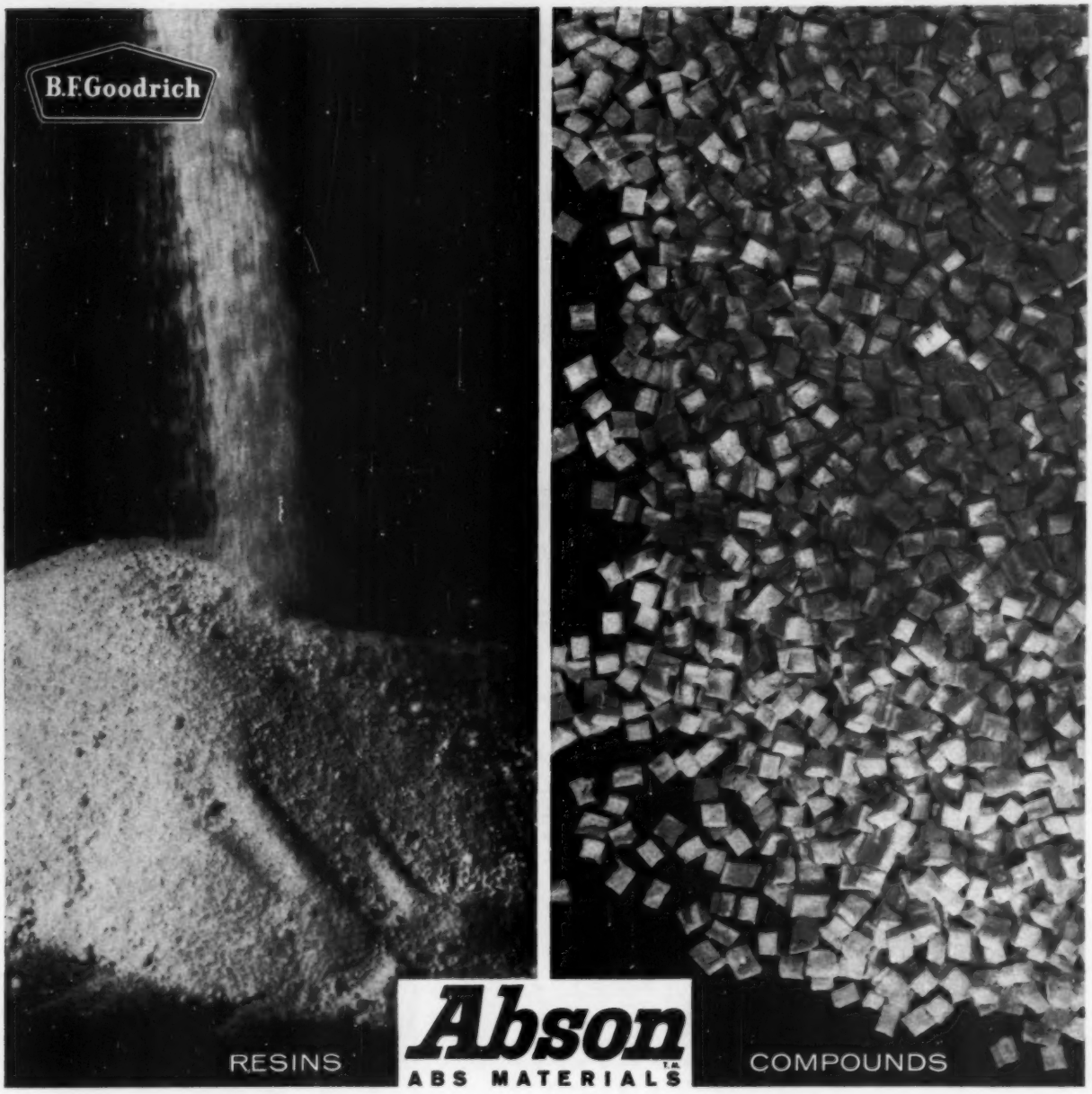

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Please send Abson Service Bulletin G-22 to:

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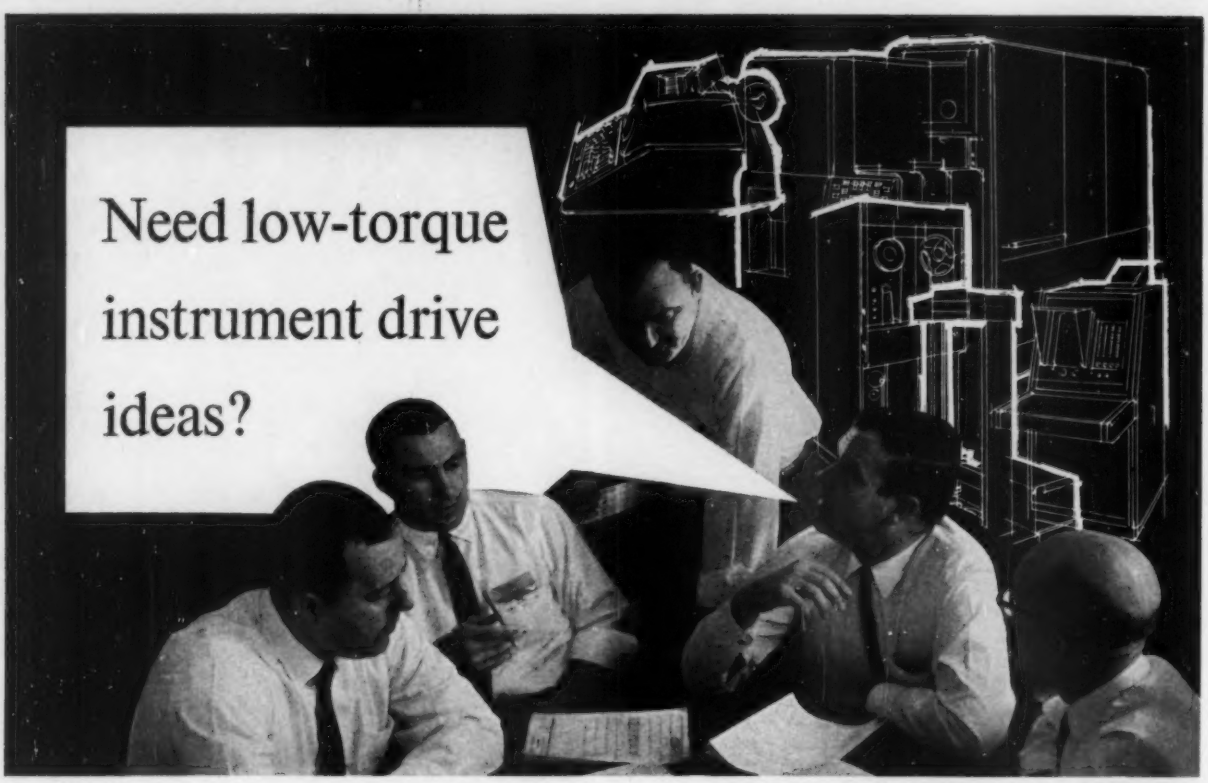
CIRCLE 85 ON READER SERVICE CARD 85



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. . . but not on your payroll.

***Advanced Control Engineering Specialists**

. . . do not cost you a penny—but they *could* open new markets, strengthen old ones . . . make possible product performance breakthroughs never before possible! The Warner ACES*—a thoroughly experienced and imaginative group of electric clutch and brake design engineers (who work with *your* men) can bring your company experience gained in hundreds of applications of low-torque drives.

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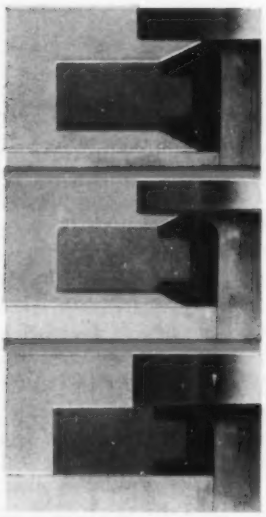
introducing the NEW

Precision Para-seal®

Photographic enlargements show the flow of sealing member under various stages of compression.



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FEATURES:

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of silent, synchronous power assembled in every *

HANSEN SYNCHRON® TIMING MOTOR

Manufacture of long-life, Hansen SYNCHRON Timing Motors is quality-controlled throughout, to make them the *best* synchronous motors for industrial and commercial applications. Skilled, experienced workers assemble Hansen SYNCHRON motors to rigid standards. Each motor undergoes 51 separate tests and inspections before shipment, insuring users of the ultimate in silent, continuous, synchronous power for specific timing applications.

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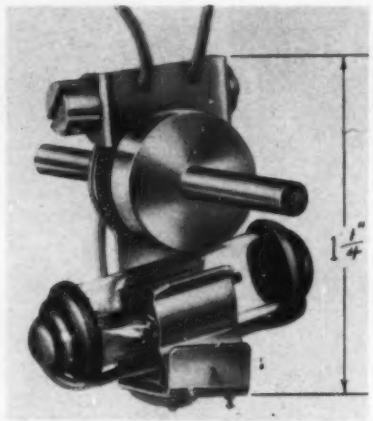
output. Available in several sizes and designs. **Chicago Miniature Lamp Works, Dept PE-1, 1500 N Ogden Ave, Chicago 10, Ill.**

Circle 309 on Reader Service Card



Mercury switch holder . . . permits two different kinds of in-service adjustment. One provides adjustment for critical point of actuation. The other regulates degree of over-tilt, controlling differential between on and off. Can be supplied for different sizes of switches. **Frank H Dougherty, 405 Atkins Ave, Lancaster, Penna.**

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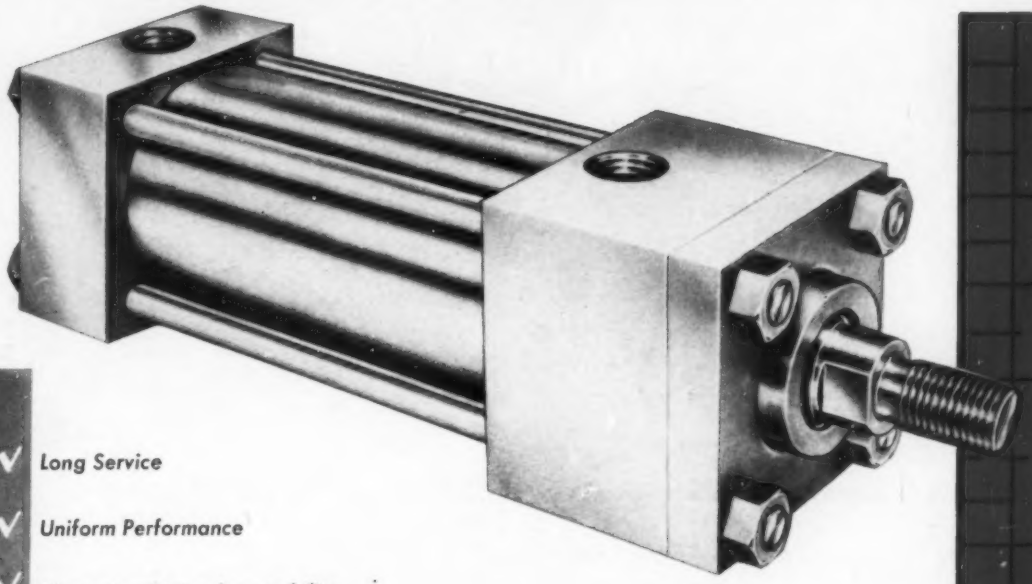
Valve minimizes line shock . . . in hydraulic or pneumatic circuits by means of its tapered plug and controlled linear flow. Flow of viscous oil is linear through valve's tapered orifice during opening and closing cycles. Flow may be regulated from 0 to 1 gpm at 400 psi through standard $\frac{1}{16}$ in. orifice. Opening or closing cycle is ¼ sec. Rated for 400 psi differential pressure with special versions for up to 600 psi. Will operate in any position on ac coil voltages of 6 to 440 v (50 or 60 cps), or 6 to 220 v dc. Less than 3 in. overall height with 1⅜ in. dia brass body, weight is 1 to 1 lb, 6 oz. **Allied Control Co, Inc, 2 East End Ave, New York 21.**

Circle 311 on Reader Service Card

Displacement transducer . . . for mechanical applications such as checking dimensions of work, thickness gaging, wobble detection, position checking has linear range displacement of ±0.500 in. A built-in

continued, page 94

NEW O-M SQUARE-HEAD AIR AND HYDRAULIC CYLINDERS GIVE THE PERFORMANCE YOU EXPECT . . . AND MORE



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Air—(rated 200 psi)
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Meet JIC Standards 1½" to 14" Bores

Made of the highest quality materials and seals, these new components combine modern design, the latest and best engineering advancements with O-M specialized "know how" and precision workmanship.

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Construction features include brass cylinder barrel, chrome-plated, high tensile steel piston rod with a minimum yield strength of 90,000 to 100,000 psi. Rolled and machined steel heads and extra long cartridge-type rod bearing assure perfect alignment of piston rod.

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Similar in many construction features to Series "K", but specifically designed for hydraulic service. Incorporate vee-type rod packing and a cylinder barrel of micro-honed steel tubing which are best suited for hydraulic operations.

With the addition of the new Series "K" and "L" to the Ortman-Miller major line of air and hydraulic cylinders, you can now rely on O-M for *all* of your low and medium pressure cylinder requirements. Both Series "K" and "L" are dimensionally interchangeable with other cylinders of a like type. Fabricated, precision steel mounts and accessories assure precise mounting.

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☐ 115A–Series "K" ☐ 116–Series "L"

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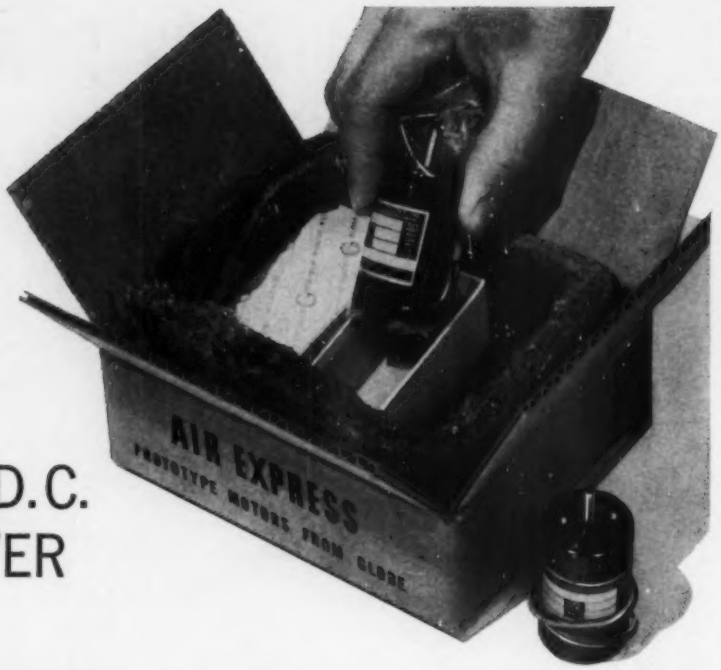

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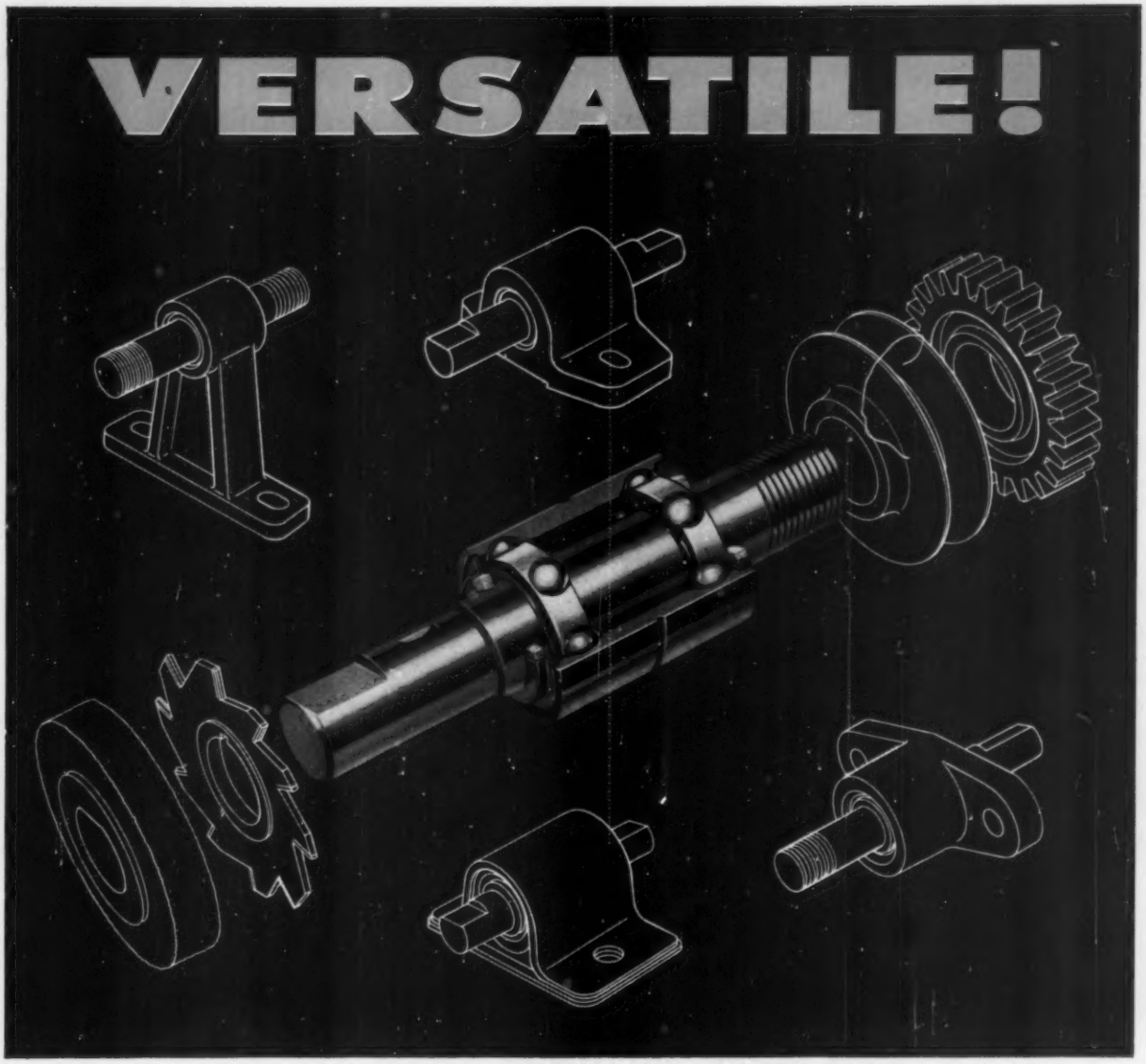

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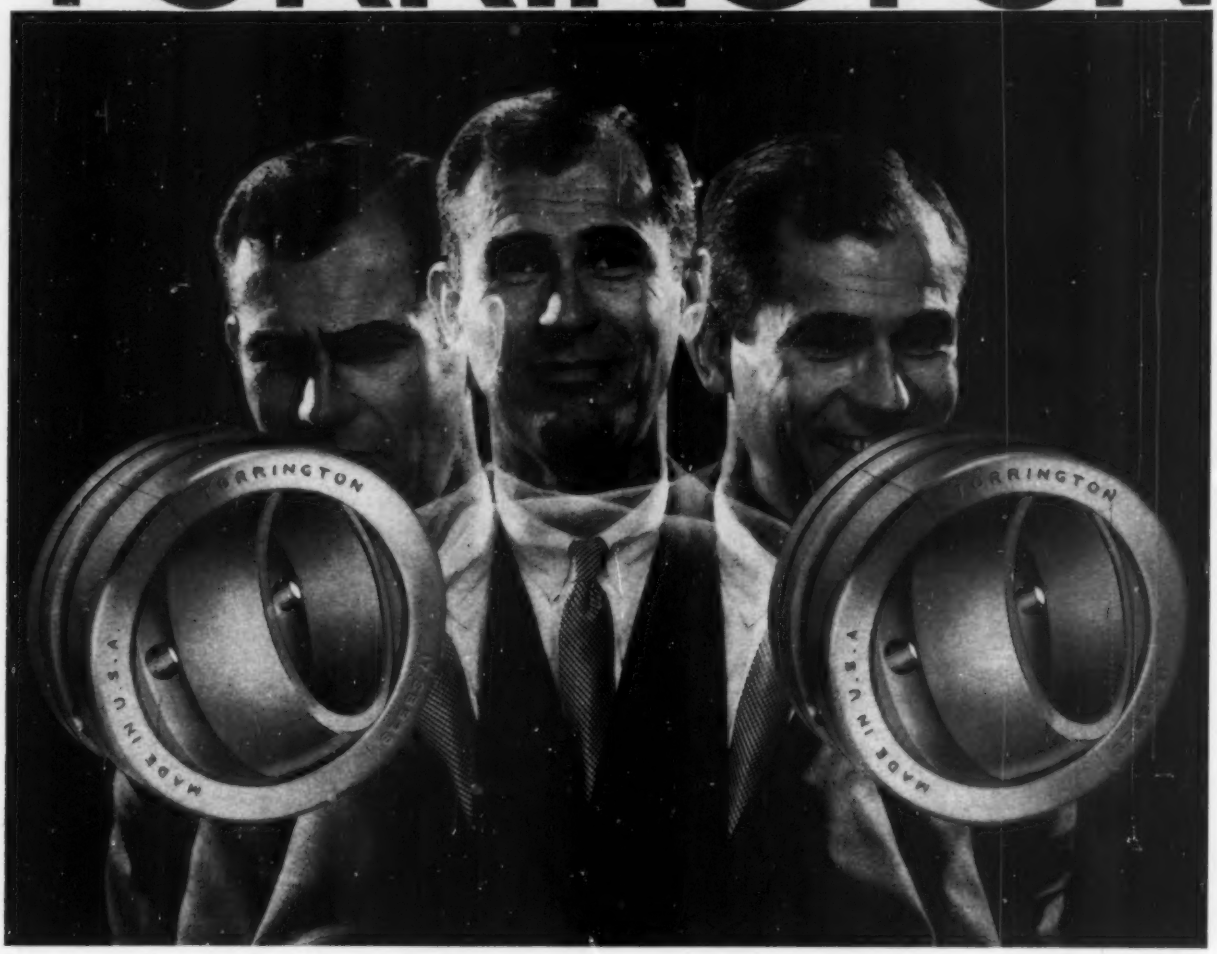

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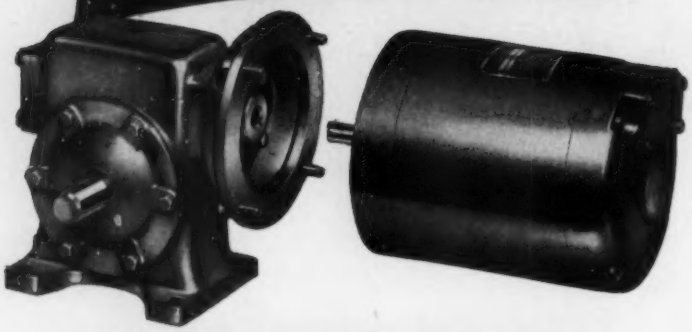
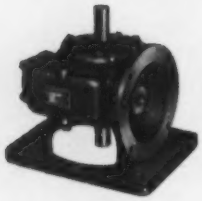
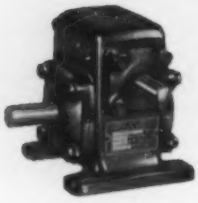
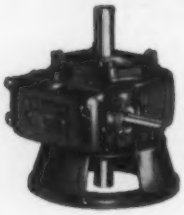


PERFECTION
Worm Gear
SPEED REDUCERS







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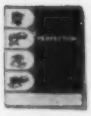

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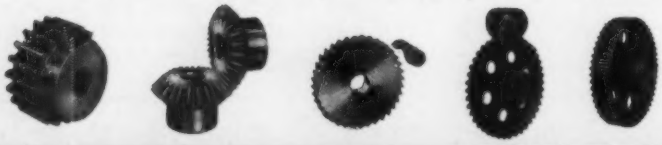
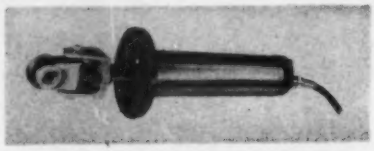
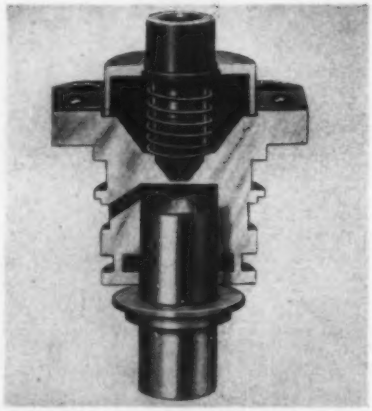


AMERICAN STOCK GEAR DIVISION
PERFECTION GEAR COMPANY, HARVEY, ILLINOIS



mechanical zero adjust is provided, together with a sealed but accessible range adjust. Roller end is equipped with precision bearings capable of withstanding shock loads and high speeds. Can be supplied with differential transformer with linear range ±0.1 in. for shorter stroke. **Automatic Ringing & Controls, Inc, King of Prussia, Penna.**

Circle 312 on Reader Service Card



Pressure change separates magnets in indicator, permitting red button to pop up and providing visual signal. Clogging, contaminant buildup, pump malfunction causes pressure to enter through top passage into chamber between upper and lower magnets. This depresses lower magnet and permits top one to rise. Actuating pressure (1.5 to 100 psi) can be adjustable or permanently set at factory. For system working pressures to 10,000 psi and operating temperatures of −65 F to 275 F. **Pall Corp, 30 Sea Cliff Ave, Glen Cove, NY.**

Circle 313 on Reader Service Card

Single reduction gearmotor . . . designed for direct connection to driven machine is available with NEMA style C or D brackets in 9- and 10⅞-in. dia face plate, respectively. Windings are asbestos-protected, castings are normalized, gears are honed and pinions have solid shanks. Only slower speed gears dip into oil reservoir, providing lubrica-

continued, page 103

Along with outer space . . .

the T-J Spacemaker is still making

BIG NEWS

The T-J Spacemaker cylinder line is not now, nor ever has been, a probe into outer space. It is offered as a practically designed, research engineered and time tested product. Its Spacemaker feature (no tie-rods) and rugged construction gives greater strength, saves space and reduces costs in all power drive applications. The Spacemaker is available in a complete range of bore sizes and strokes, air or hydraulic, and contains many *plus features* and extras as STANDARD . . . NO EXTRA COST! Write Tomkins-Johnson, 2425 W. Michigan Ave., Jackson, Mich. for Bulletin #155-4 and for full particulars, today.

RIVITORS

CLINCHORS

CYLINDERS

CUTTING TOOLS

T-J TOMKINS-JOHNSON
JACKSON MICHIGAN

NEW WAYS *to use...*

HEIM *Unibal*® BALL BEARINGS

A significant contribution to bearing technology was made by HEIM when they first presented their exclusive and patented revolutionary concept in the design and method of manufacturing ball bearings.

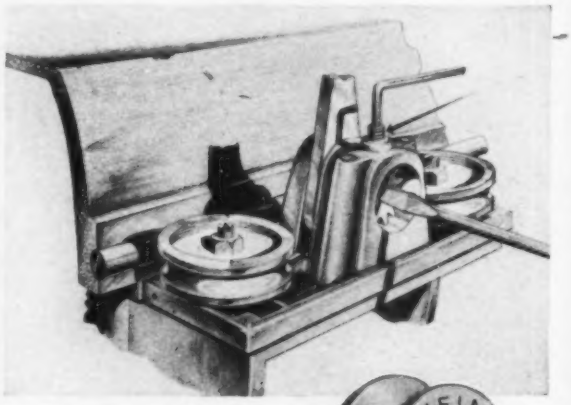
These new bearings have solid, unbroken, machined inner and outer raceways; deep, burnished ball grooves; and a full complement of balls. There are no retainers, and the balls travel in races uninterrupted by counterbored rings or filling slots.

Ball Bearings for Special Purposes

With the Heim advanced techniques in ball bearing construction, additional features can be incorporated in the production of these bearings to allow wider applications not before thought possible.

For example . . .

"Sawsmith," made by Magna American Corporation, is claimed to be the world's finest Radial Arm Saw. It has four Heim Ball Bearings, specially designed with grooved outer members, which serve as glide bearings against the arm guide rails. These are mounted on an eccentric shaft for easy adjustment.



The Heim method presents the design engineer with virtually unlimited possibilities, such as . . . compact ball bearings with grooved outer members, single or double row types, plain or flanged outer members, and made for round, square or hexagonal shafts.

Production of special forms depends on volume requirements.

Miniature Ball Bearings

Heim's unique process produces a bearing with a full complement of balls, deep, unbroken, burnished ball grooves, with maximum capacity for radial and thrust loads.

The miniature series is made in open type, with one or two shields, or with extended inner races for clevis mounting.

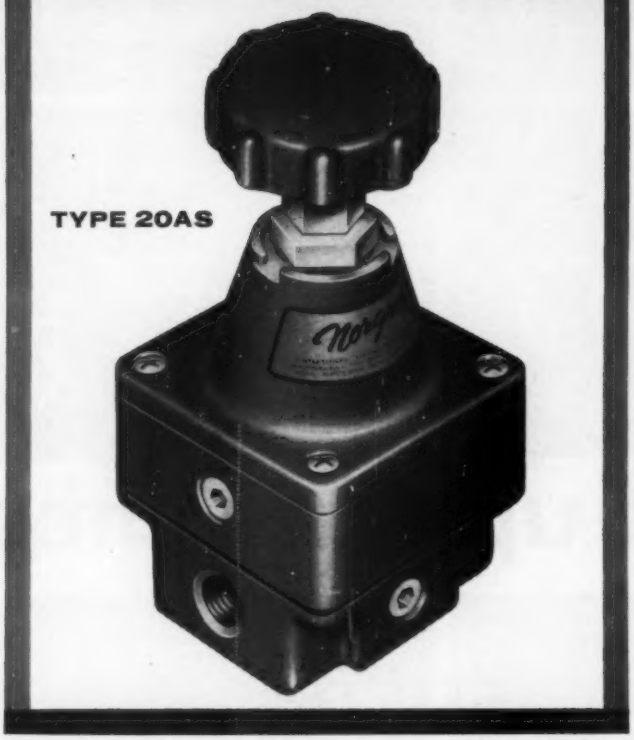
These miniature bearings with outside diameters from .1250 to .5000 are made with characteristics perfectly adequate for many applications now using precision bearings.

Send for new catalog of standard ball bearings, see the Heim bearings distributor, or write our engineering department for information on special forms.

HEIM BALL BEARINGS

Made for **UNIVERSAL BEARINGS CORP.** *Fairfield, Connecticut*

NEW



NORGREN PRECISION PRESSURE REGULATOR

high sensitivity and exact accuracy of air pressure regulation

The new Norgren Precision Pressure Regulator, Type 20AS, is designed for air-gauging, laboratory use, pilot regulation and other applications where a high degree of accuracy and sensitivity is required for air pressure regulation. Operation of the new Type 20AS regulator is characterized by the following:

1. **Accurate regulation at all flows up to the maximum flow recommended for ¼" pipe. This is more than 2 times the flow previously possible with instrumentation regulators.**
2. **Immediate response and high sensitivity.**
3. **Exact repeatability and freedom from drift over short or long time operations.**
4. **Accurate regulation—even at delivery pressures below 1 psi.**

SPECIFICATIONS:

0-60 psig secondary pressure
0-150 psig primary pressure
32° to 160° F temperature range
¼" pipe size

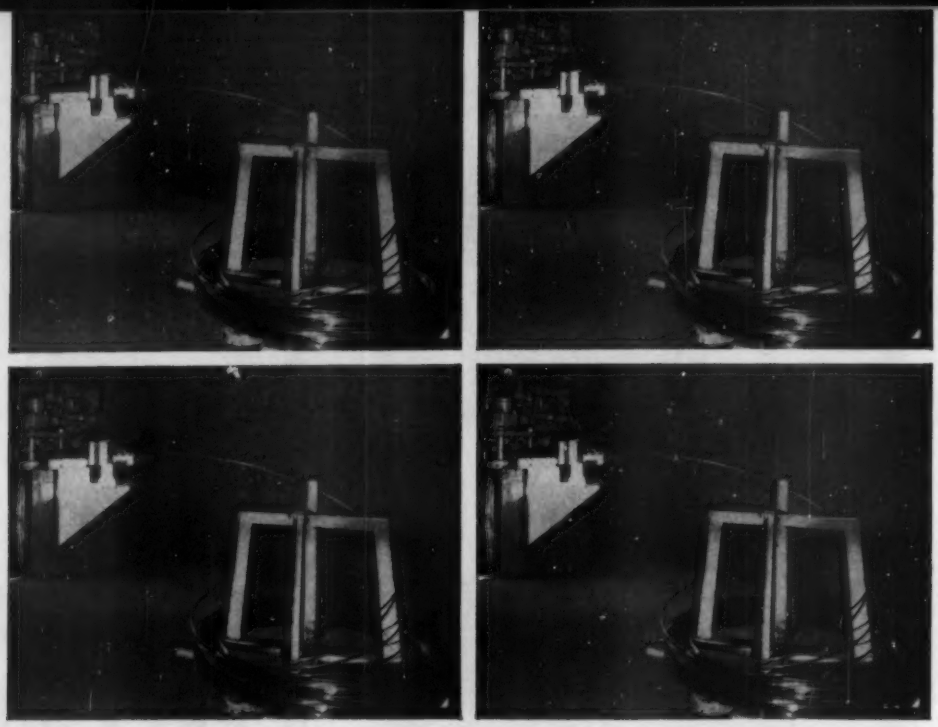
For complete technical information about the new Norgren Precision Pressure Regulator, call your nearby Norgren Representative listed in your telephone directory—or write factory for brochure NA-7.

Founded in 1926

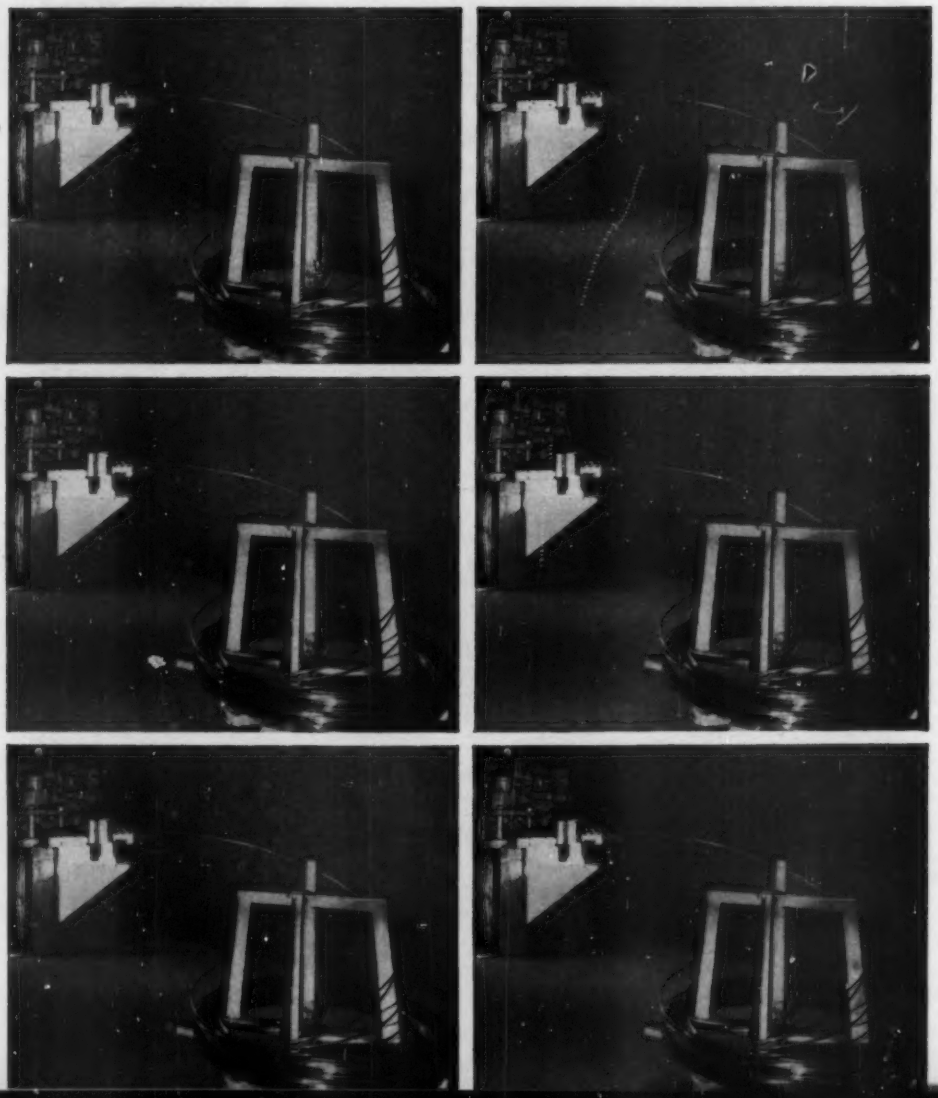
C. A. NORGREN CO.

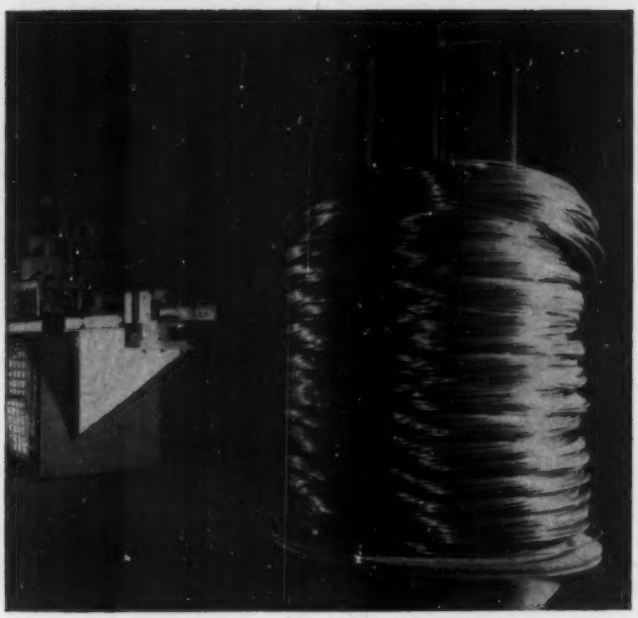
3428 SOUTH ELATI STREET • ENGLEWOOD, COLORADO

CIRCLE 97 ON READER SERVICE CARD 97



Why set up ten times . . .



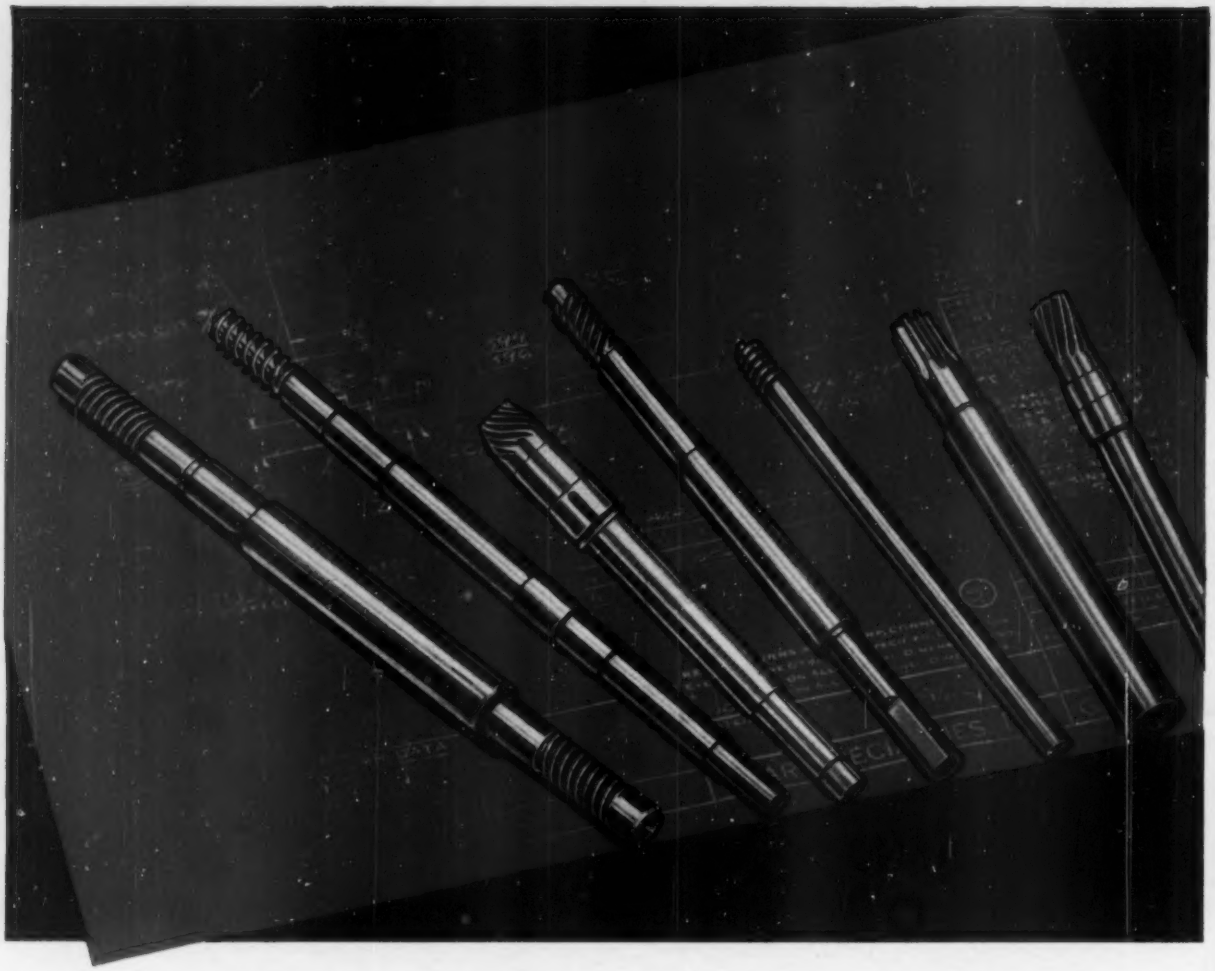


. . .when once will do?

It's a simple matter to add up the savings heavyweight wire coils can give you. How much time does it take you to shut down a machine and start a new coil through? Multiply that by the number of times you have to do it in an 8-hour shift. Then figure that as much as 90% of that lost time is sheer waste. Because you could be using AS&W heavyweight coils that contain up to ten times as much wire in one continuous length. **Other savings:** less handling, less storage space needed, even lower scrap loss. Heavyweight coils aren't the only road to cost reduction: *American Steel and Wire offers a dozen different wire packages.* One of them is designed just right for your operation. Let us look at your set-up and recommend the best package . . . a simple step to increased production. Call our nearest sales office or write American Steel and Wire, Dept. 1489, Rockefeller Building, Cleveland 13, Ohio.

Innovators in wire

American Steel and Wire
Division of
United States Steel



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WORM GEARING • RACKS • THREAD GRINDING

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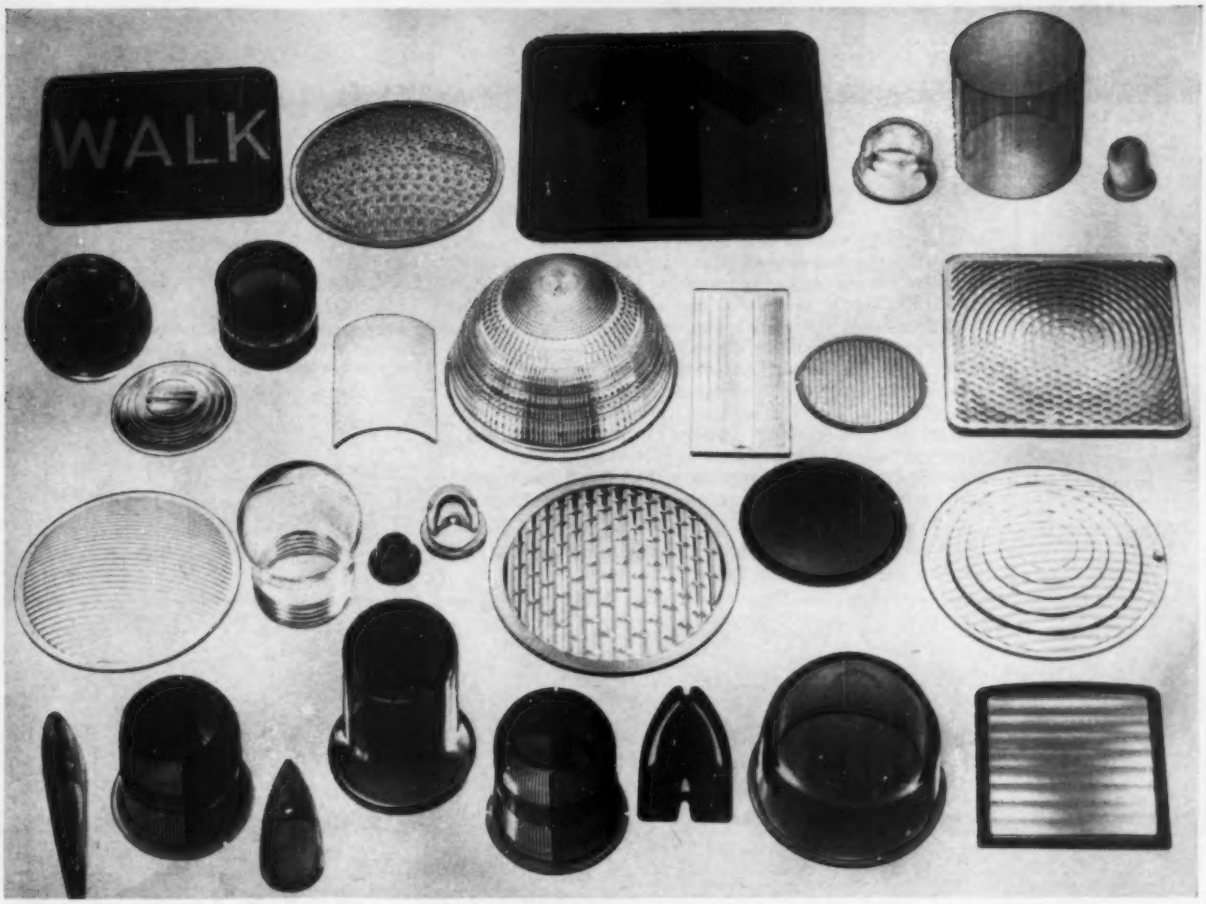
Our experienced engineers are at your service to discuss any Small Gearing problem with you—and help you get better answers. Call or write us—now.

SEND FOR G.S. *illustrated folder! See where and how we mass-manufacture Small Gearing to uniformly fine tolerances. Folder contains 23 pictures of Small Gears, plant view, Diametral and Circular Pitch Tables. Ask for your copy on company stationery, please!*

45 Years of Specializing in Small Gearing!



Each of these Kopp glass parts was engineered to do a specific job

REPRESENTATIVE KOPP PRODUCTS
(Reading from top, left to right)

TRAFFIC signal lens for pedestrian control
Traffic signal lens for street and highway control
Traffic lens for multiple-lane control

MARINE floating light lens
Marine color filter
Marine stern light lens

RAILROAD lantern globe
Railroad switchlamp lens
Railroad fresnel globe

SURGICAL heat absorbing lamp filter

LIGHTING refractor for street lighting
Lighting lens—flat fresnel for interior lighting
Lighting museums and art galleries—color-correcting glass
Lighting lens—beam control

FLOODLIGHTING cover glass

INDUSTRIAL vapor-proof globe
Industrial control board indicator lens
Industrial sight glass

SWIMMING POOL color-correcting lens

THEATRICAL lighting color filter
Theatrical and TV spotlight lens

AIRCRAFT wingtip lens
Airport runway lens
Aircraft wingtip part
Airport runway color filter
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AUTOMOTIVE turn signal arrow
Automotive dome

DENTAL light color-correcting filter

Perhaps we can help you with your problem . . .

Whether you need a lens, color filter, cover glass, or some other special part, Kopp can engineer and custom-produce a product to meet that need. It will be designed to provide the right light and color transmission and distribution, heat-resistance, mechanical strength—in fact, the exact combination of properties needed to do your special job. Write us about your needs.

KOPP GLASS, Inc. • SWISSVALE, PENNSYLVANIA

KOPP GLASS, INC. PE
SWISSVALE, PA.

☐ Please send FREE copy of "This is Kopp Glass."
☐ Enclosing preliminary drawing and application information for your suggestions.

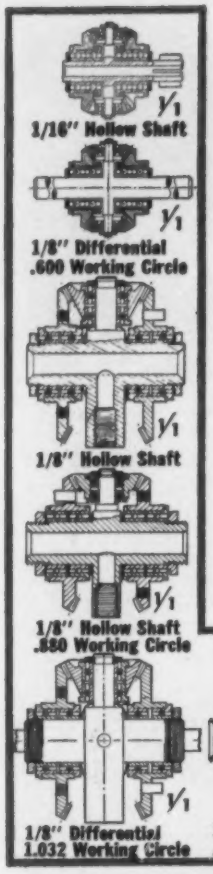
NAME_____

COMPANY_____ TITLE_____

ADDRESS_____

CITY_____ STATE_____

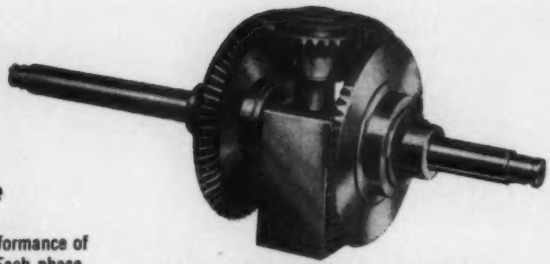
CIRCLE 101 ON READER SERVICE CARD 101



Dust-Free *PRECISION DIFFERENTIALS* by Arch Boost Servo Performance

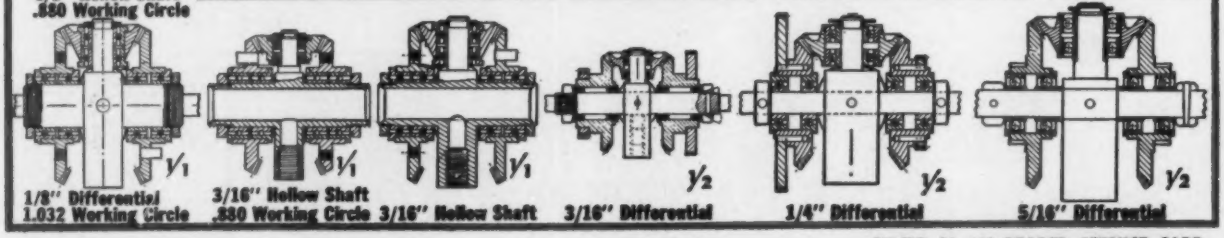
In today's highly sensitive servo systems, optimum performance of precision differentials depends upon many factors. Each phase, from design to manufacture and assembly, must be critically controlled with special emphasis on dust and temperature control. At Arch Instrument, all assembly, testing, calibration and packaging of precision differentials is performed in a new and specially built dust-free and temperature controlled "white room" to assure you tolerances and performance far beyond the ordinary. In addition, the Arch line - consisting of ten models from 1/16" to 5/16" - offers greater design flexibility with interchangeable end gears and modifications of backlash and breakaway torque to customer specifications. To learn more about Arch's ability with precision differentials, write or phone for further information.

Arch INSTRUMENT COMPANY, INC.
101 HOLMES STREET, NO. QUINCY 71, MASSACHUSETTS



DESIGN LAYOUT FOLDER

Available to engineers, designers and purchasing agents. Contains differential tracings for use as an underlay in design layout work.



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For...
Pressure and Torque Applications
Actuating
Conveyor Adjustments
Machine Adjustments
Leveling Systems
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Testing Equipment

Models, one ton and up. Can be driven by motors or manually operated . . . synchronized by interlocking shafting and gear boxes. Various screw attachment heads available . . . also stainless steel or hollow screws.
SEND COUPON FOR FOLDER TODAY!

THE JOYCE-CRIDLAND COMPANY, DAYTON 3, OHIO

Rush folder on Worm Gear Screw Jacks!

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To Protect Threads, Tubes, Valves, Components, etc. from Dirt and Mishandling
Available from Stock

ALUMINUM		POLYETHYLENE	
Pipe Caps	"C" Series AN & SAE Fittings.	"200" Series Tapered Plug & Cap	"LT" Series Tube Caps
Pipe Plugs	"P" Series AN & SAE Fittings	"TY" Series Thick Wide Flange Tapered Plug & Cap	"600" Series Single Thread Pipe Caps
"D. O. C." Series Drive-on Caps	"C-FT" Series to all Thread Specifications	"EP" and "EE" Series Elec. Conn. Plugs & Caps	"TC" Series Self-Sealing Caps—for AN & SAE Fittings
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Special Closures Manufactured to Customers' Specifications, of Aluminum or Polyethylene. Quotations on request, furnish description desired including thread size.

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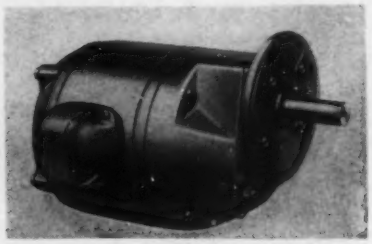
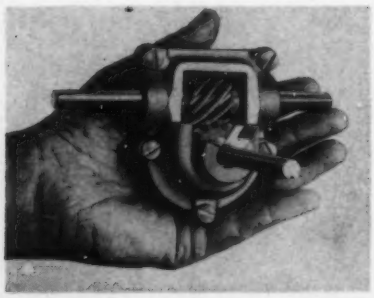
CIRCLE 43 ON READER SERVICE CARD



tion without churning. Available from 1 to 5 hp, 230 to 780 rpm in drip-proof, totally enclosed and explosion-proof designs. **US Electrical Motors Inc, Box 2058 Terminal Annex, Los Angeles, Calif.**

CIRCLE 314 ON READER SERVICE CARD



Right-angle 1:1 gear drive . . . is self-aligning and infinitely adjustable. Has hardened helical gears and aluminum housing. Right- and left-hand units available. Can be used on same drive train to operate drives in opposite directions at same time. **Tol-O-Matic, Inc, 246-10th Ave S, Minneapolis, Minn.**

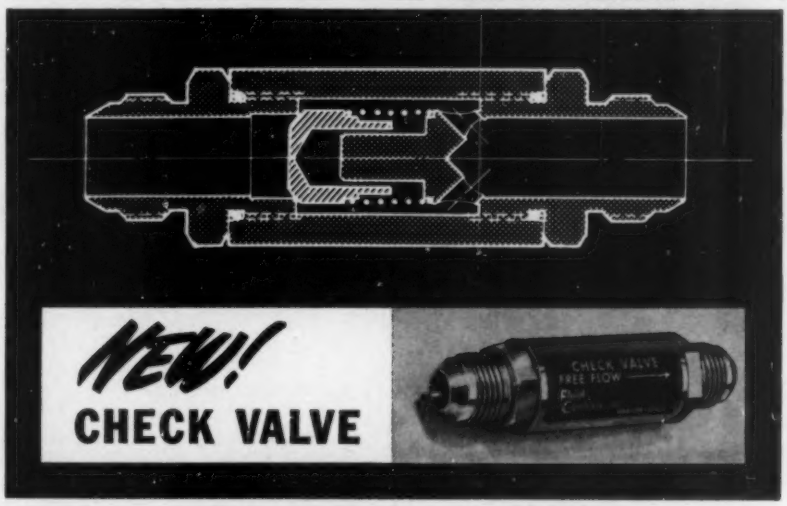
CIRCLE 315 ON READER SERVICE CARD

Counter-clock combination . . . can be reset by front panel controls for any given amount of time counting, up to 99,999 hr or 9999.9 min depending on model. A clock is also included in unit, with digital readout for either 12 or 24-hr periods. Withstands

continued, page 104

Mono Cord
NO SPLICE RINGS
are better because the principle hazard found in ordinary seal rings and belts has been removed by Western's Mono Cord one-piece construction. In addition, dimensional requirements are maintained, quality controlled, and service vastly improved—all at no extra cost.
Don't use a spliced ring for technical seal applications, but profit from nearly 60 years experience—specify Mono Cord rings by Western.
Write or phone for information, literature or a visit by our sales engineer in your area.
Mono Cord
SINCE 1908
WESTERN RUBBER CO.
GOSHEN 9, INDIANA
Molded and Lathe-Cut Rubber Parts for All Industries

CIRCLE 44 ON READER SERVICE CARD



. . . with male end fittings

- Low Pressure Drop
- Safe — won't stick open
- Tight metal seal
- Rugged — all steel construction

- For oil to 5000 psi
- Sizes ¼" thru 1¼" pipe (NPTF) or S.A.E.
- Combinations of NPTF and S.A.E. fittings

Write for detailed literature

Fluid Controls, inc.

Manufacturers of Hydraulic Valves and Devices

Relief Valves • Check Valves • Restrictor Valves
Needle Valves • Pilot Check Valves • Special Valves
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HEYCO
NYLON
BUSHINGS!

HEYCO
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BUSHINGS

For standard and special wires and cables

The Approved Standard for Insulating and Anchoring ELECTRICAL CORDS & CABLES

Approved HEYCO
Snap Bushings

Insulation and mechanical protection for electrical wire & cable, hose, tubing & rope—a bearing for moving parts.

Finger pressure snaps and locks bushing into panels of varying thickness up to ¼"

HEYCO JUNCTION-TERMINAL BUSHINGS

Miniature Insulated Receptacle
Eliminate "Pig-Tail" Wire Leads
Mate with 3/16 or 1/4" female terminals

COLOR CODED

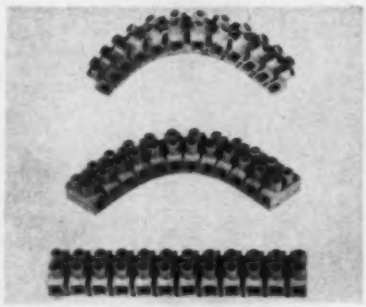
HEYCO®

HEYMAN MANUFACTURING CO.
KENILWORTH 3, NEW JERSEY

FREE SAMPLES: Which bushings would you like?

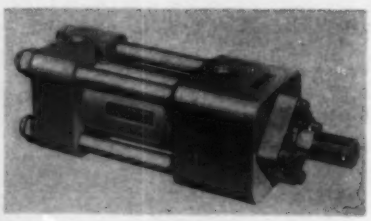
shock of 2000 psi. Accuracy 0.1%. Measures 7½ x 6 x 3⅛ in.; weighs 5 lb. **Pennwood Numechron Co, Electronic Timing Div, 7249 Frankstown Ave, Pittsburgh 8, Penna.**

Circle 316 on Reader Service Card



Flexible terminal block . . . made of polyester will accommodate wire up to #10. Electrical rating of block is 25 amp. Block containing 12 terminal units measures 3¾ x ⅝ x ½ in. high, with 11/32 in. between terminal centers. Block can be bent in any direction and cut into sections. **National Tel-Tronics Corp, 52 St Casimir Ave, Yonkers, NY**

Circle 317 on Reader Service Card



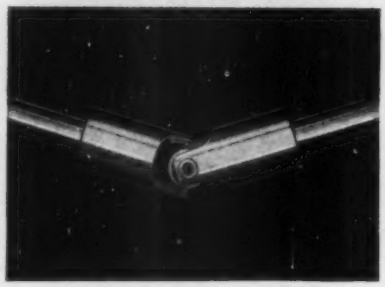
Hydraulic cylinders . . . in 2000-psi models for use in such applications as machine tools; 2000-3000 psi units for all-purpose use meeting JIC specs; and in heavy duty 5000-psi models are available with bore sizes of 1-⅛ to 14 in., in 17 different types of mountings. **Denison Engineering Div, American Brake Shoe Co, 1160 Dublin Road, Columbus, Ohio.**

Circle 318 on Reader Service Card

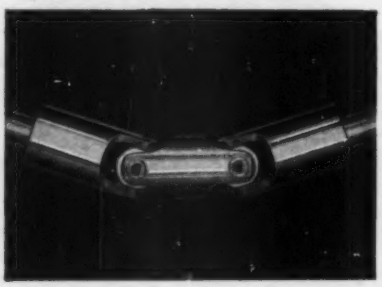
Right-angle check valve . . . which may also be used as a low pressure relief valve has external cracking pressure adjustment that permits resetting while in operation. Removable end cap assembly permits cleaning without removing from line. Body is of one-piece, all-steel design and guided poppet is said to have non-

continued, page 112

How Curtis helped a design engineer "BEAT THE HEAT"



This single universal joint in a ribbon-stripping machine was operated at a 34° angle. The joint heated up, wear was excessive. (Curtis Joints have been tested at angles up to 37°, but we do not ordinarily recommend angles greater than 30°.)



Curtis engineers recommended a *double* Curtis joint, which reduced the angle to 17° per joint. Result: no overheating, improved efficiency, longer life.

You can depend on Curtis engineering in any problem of angular power transmission. And you can depend on

CURTIS UNIVERSAL JOINTS

because our catalog torque and load ratings are substantiated by constant tests under production conditions.

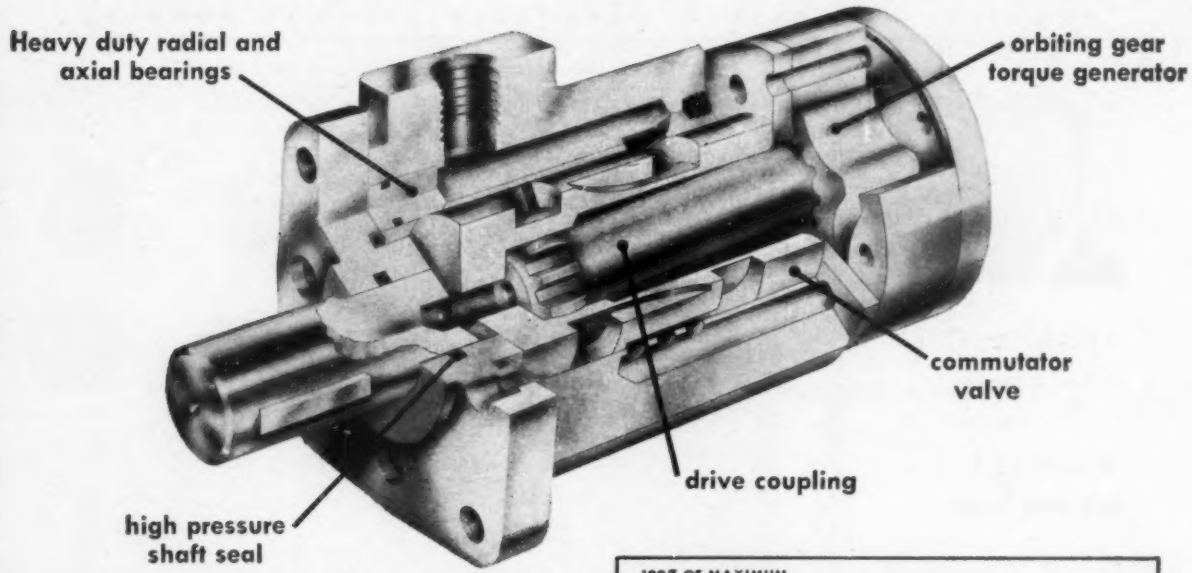
14 SIZES ALWAYS IN STOCK —
⅜" to 4" O.D. (6" joints on special order)

Not sold through distributors. Write direct for free engineering data and price list.

TRADE MARK CURTIS
UNIVERSAL JOINT CO., INC.
1111 Birnie Avenue, Springfield, Mass.
As near to you as your telephone

EXCLUSIVELY A MANUFACTURER OF UNIVERSAL JOINTS SINCE 1919

New Hydraulic Motor Design Provides High Torque at Low Speeds



ORBIT MOTORS®...

DELIVER MORE TORQUE PER LB and AT LESS COST

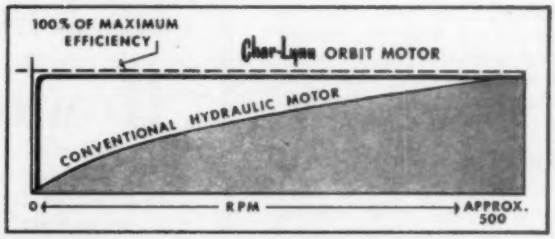
The Orbit principal utilizes an internal gear mechanism to act both as a fluid displacement motor and a gear reducer. The outer segment is a stationary part of the motor housing and has internal gear teeth which mesh with corresponding teeth on a smaller gear or rotor which rolls inside the outer gear, turning about an eccentric axis in an ORBIT.

The rotor gear rolls through six complete orbits during each single rotation of the output shaft. Thus an effective speed reduction of 6-to-1 is obtained. The use of seven fluid chambers with the inherent 6-to-1 ratio provides 42 fluid power cycles per shaft rotation, a distinct advantage in obtaining smooth rotation.

As it rotates, the rotor gear causes a continuous opening and closing of the spaces between the teeth. Half of these spaces are subjected to fluid pressure and the opposed half is connected to the return section of the motor.

The rotary commutator valve distributes the fluid so that the pressured space rotates in phase with the rotor gear, thus causing continuous rotation. Motion of the rotor gear is transmitted to the output shaft by a coupling which has crowned involute splines to match the bores of the output shaft and the rotor gear.

The high pressure shaft allows ORBIT MOTORS to be operated "in series" without external drain lines.



High efficiency over complete operational range

- **Speeds from 0 to 800 rpm**
- **Torques to 3300 inch lbs.**
- **Starting torque substantially equal to running torque**
- **Full reversible—instant starting, stopping**
- **Only 3 moving parts**
- **4 types of mountings available**
- **3 port sizes, 7 power element selections**
- **Compact, light weight**
- **Eliminates costly and complicated power transmissions**
- **High volumetric and overall efficiency**

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RB&W FASTENER BRIEFS

RUSSELL, BURDSALL & WARD BOLT AND NUT COMPANY

Technical-ities

by Fred E. Graves

A word about bolt load levels

If you tighten a bolt beyond its proportional limit it deforms plastically. Materials' engineers call the stress where this permanent set is measurable the bolt's yield strength.

NO HARM IN OVERTIGHTENING

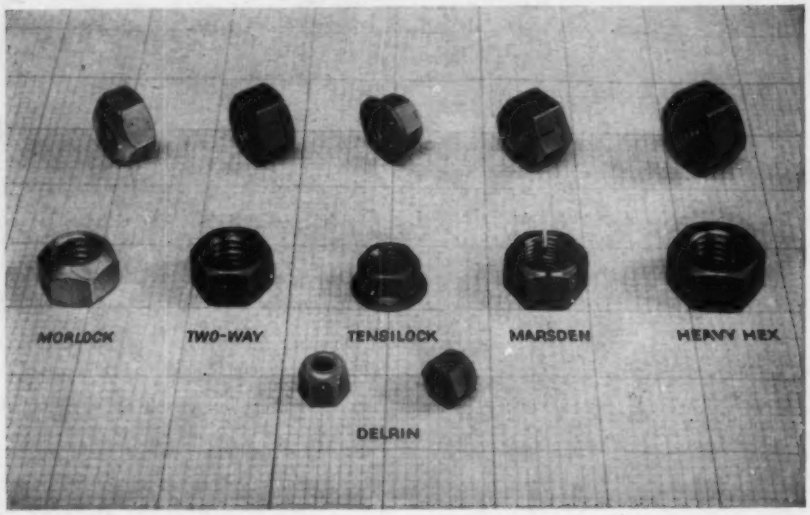
You can tighten up to yield strength—and even beyond. Where permanent connections are made this is recommended.

Naturally, pitch of the external threads increases as a screw stretches. Conversely, because a nut undergoes compression the pitch of its internal threads decreases.

This results in a cumulative off-lead condition. In most instances, it's not practical to re-use a bolt stressed beyond its elastic limit.

For the usual type of solid joints, the recommended stress level for SAE Grade 2 fasteners is 40,000 psi; for Grade 5 (high strength), it's 60,000 psi. While below yield strength, these levels provide high bolt preload—good assurance against loosening and fatigue.

Always specify that the assembler torque a bolt or screw to the recommended level. It's the usable 'muscle' you pay for in fasteners. If you don't use it, chances are somebody's money is being wasted. Equally important, *the joint isn't as strong as it could be.*



How to keep a nut in its place

LOCKING nuts are used to develop clamping force on a vital joint . . . or, to restrict 'end play' of movable members.

Self-locking action can be achieved by: 1) increasing thread friction, or 2) an anchoring mechanism. Examples:

PREVAILING-TORQUE LOCKING

1. Morlok® nut. Crown is processed to change phase of last thread. Hence the Morlock nut screws on easily until its last thread engages; then more on-torque must be used. Off-torque is correspondingly high. It locks anywhere on the screw.

2. Two-way locknut. Depressions staked in two opposite faces deform center thread slightly for self-locking action. Double-chamfered, it goes on from either end, speeding assembly.

3. Delrin* locknut. This metal-like plastic locknut forms its own threads. Available for light duty in #10 and 1/4" sizes, it has holding strength of 400-700 pounds, prevailing torque of 7-15 in-lbs, stripping torque of 15-25 in-lbs, depending on size. They're reusable.

HIGH THREAD TENSION LOCKING

4. Tensilock® nut. Carburized teeth bite into bearing surface, resist counter-clockwise rotation. Combining clamping with anchoring action, it requires 25% more off-torque than on-torque to loosen.

5. Marsden® nut. When torqued snug, slotted sides of this nut draw inward against screw's threads, thus creating a frictional 'bind.' Nut is capable of high clamping force too.

6. Heavy hex nut. Engineers often overlook locking action inherent in this nut. Used with high-strength screws, it develops high thread tension and a corresponding high friction on thread flanks. This not only means a stronger joint, but one that won't shake loose.

These and other lock nuts are manufactured by RB&W. Write for specific recommendations on your design problem. Russell, Burdsall & Ward Bolt and Nut Co., Port Chester, N. Y.

*Du Pont trademark.

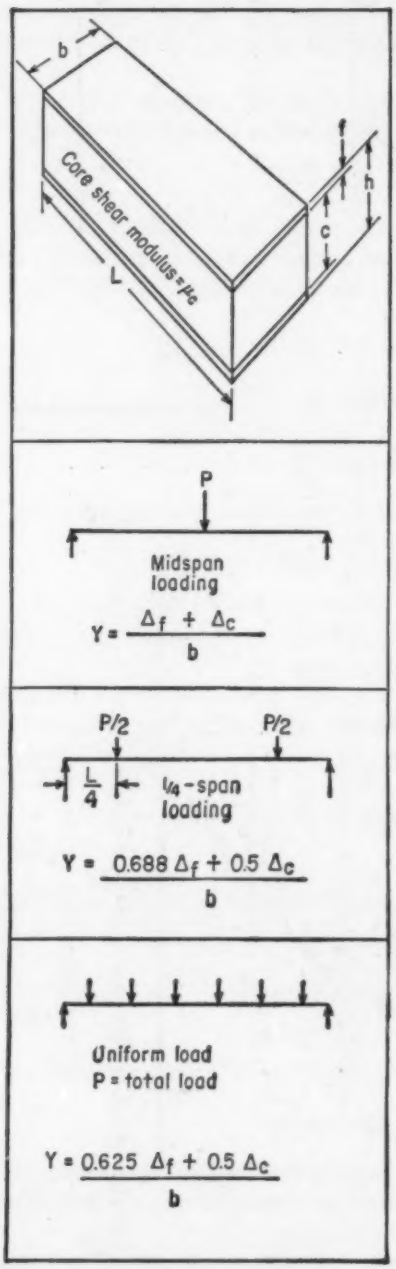
Plants at: Port Chester, N. Y.; Coraopolis, Pa.; Rock Falls, Ill.; Los Angeles, Calif. Additional sales offices at: Ardmore (Phila.), Pa.; Pittsburgh; Detroit; Chicago; Dallas; San Francisco.

Your turn

..to participate in the current problems of our profession.

Sandwich beams bring a "built-in" problem—what's the best combination of facing, core thickness and core shear-moduli?

E. J. Okragleski, body stress analyst of the Chrysler Corp at Highland Park, Mich has devised what he calls an "engineering tool" for the above type of problem—all you need is a simple formula and four alignment charts.



Loading diagrams and their appropriate formulas for maximum deflection.

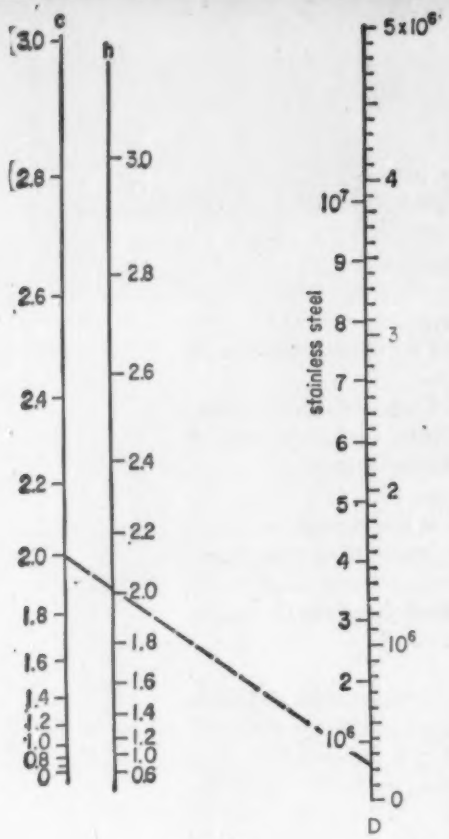
Do a quick test run-through of a sample problem: A simple beam with aluminum facings has $f = 0.010$ in., $c = 2.0$ in., $L = 20.0$ in., P (midspan) $= 50$ lb, $b = 4.0$ in.

First, find the total midspan deflection when the core shear-modulus is 9800 psi. From charts 1 and 2, $\Delta_f = 0.037$; from charts 3 and 4 $\Delta_c = 0.11$. Total deflection, then, is

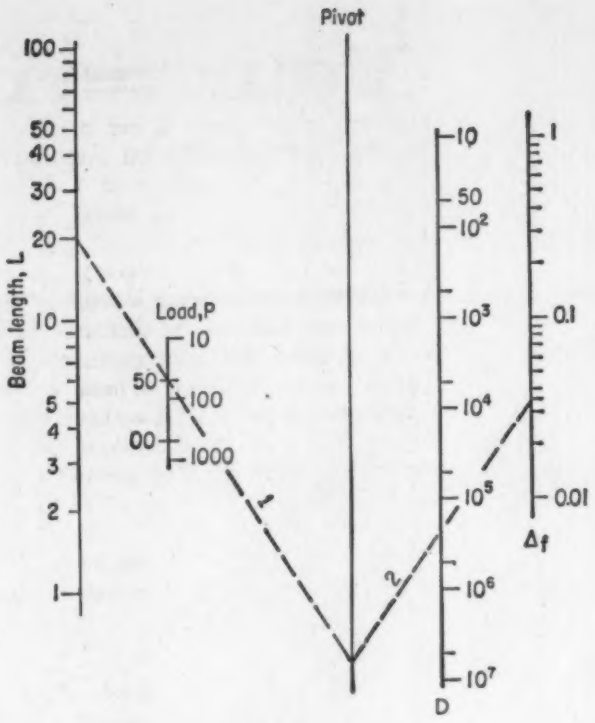
$$Y = \frac{0.37 + 0.011}{4} = 0.012 \text{ in.}$$

Chart 1 indicates that flexural rigidity will be affected most by varying c. So in Chart 4, after finding points A and B, lay two straightedges through the points and manipulate the straightedges to study the effect of varying core modulus μ_c on deflection Δ_c. This gives you quick visual aid in selecting the core material. The D scales in charts 1 and 2 are based on Poisson's ratio and the elastic moduli for stainless steel and aluminum.

see charts, next page


c
h
stainless steel
D
5x10⁶
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0
0.6
10⁷
10⁶
10⁵

1


Pivot
Beam length, L
Load, P
D
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1
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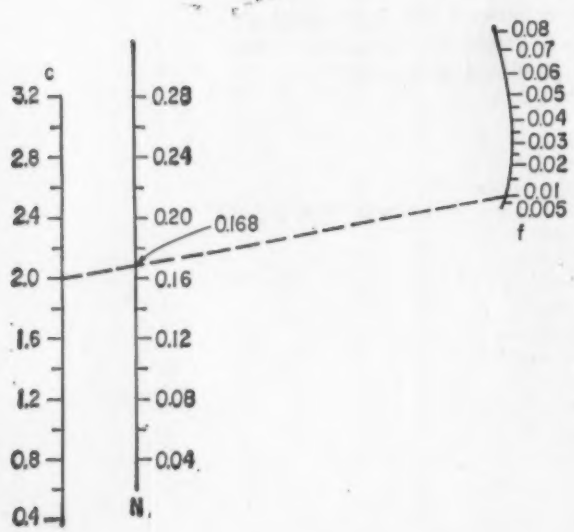
2


c
N
f
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2.8
2.4
2.0
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0.8
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0.16
0.12
0.08
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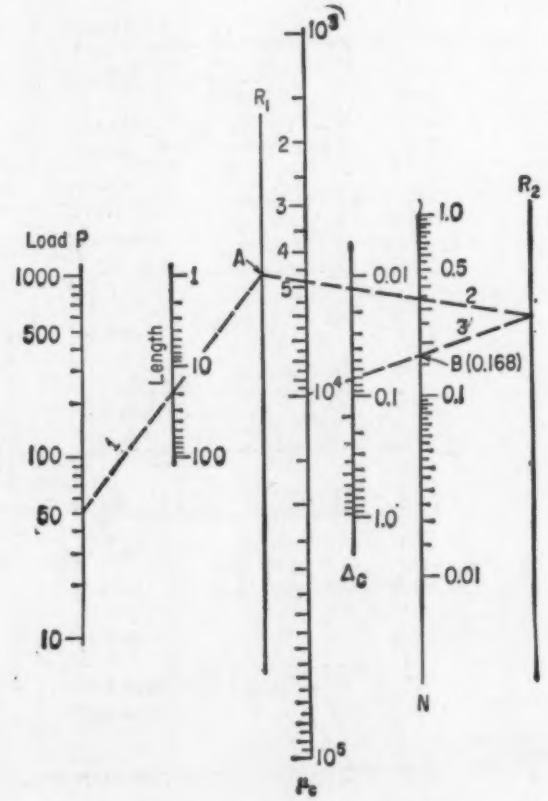
3


Load P
Length
A
B (0.168)
R1
R2
Pc
Δc
N
1000
500
100
50
10
1
10
100
10³
10⁴
10⁵
2
3
4
5
0.01
0.1
1.0
0.5

4

YOUR TURN *continued*

Here is the last lesson in our brief review of ordinary differential equations. Robert P Benedict, who first prepared this series for fellow engineers at the Westinghouse steam division in Lester, Pennsylvania, will now relinquish his temporary professorship to another instructor and another mathematical topic beginning next issue.

In this final lesson, we are going to examine two more **special differential equations that have elementary solutions.** But first, let's look back over the path we've been traveling. In the first lesson we outlined the features that classify differential equations: order, degree, linearity and homogeneity. Then, in subsequent lessons, we tackled first-order, linear equations of various kinds, and higher-order, linear equations. Last issue, we looked at two special equations, the Euler-Cauchy and Bernoulli. The two additional ones described below bring the total to nine. Memorize each of the nine general forms, and learn to recognize them. The time and misery they save by offering an easy, orderly solution, will amply repay the effort.

The Riccati equation, like the Bernoulli, is a special nonlinear, first-order, nonhomogeneous, first-degree differential equation. Its general form is

$$\frac{dy}{dx} = F_1(x) + F_2(x)y + F_3(x)y^2$$

This can be reduced to a linear differential equation. But to do it, you must first express the dependent variable in terms of a known particular solution, y_1 and an unknown function (z) of the independent variable. Thus

$$y = y_1 + \frac{1}{z}$$

and

$$y^2 = y_1^2 + \frac{2y_1}{z} + \frac{1}{z^2}$$

$$\frac{dy}{dx} = y_1' - \frac{z'}{z^2}$$

Substituting these in the original equation gives

$$y_1' - \frac{z'}{z^2} = F_1(x) + F_2(x)y_1 + F_3(x)y_1^2 + \frac{F_2(x)}{z} + \frac{2F_3(x)y_1}{z} + \frac{F_3(x)}{z^2}$$

But, because y_1 is a particular solution, it satisfies the original equation and all the boldface terms in this auxiliary equation can be divided out, leaving only

$$z' + F_2(x)z + 2F_3(x)y_1z = -F_3(x)$$

which is a linear equation and therefore has a general solution of the type given for first-order nonhomogeneous equations as described in a previous lesson.

Example: The equation

$$y' - x^2y^2 + x^4 - 1 = 0$$

can be written in the form of the Riccati equation by assuming that the $F_2(x)$ y term is zero

$$y' = (1 - x^4) + (0)y + x^2y^2$$

Choosing the particular solution $y_1 = x$, and with $z = 1/(y - y_1)$, convert the equation to the form derived above. This substitution gives

$$z' + 2x^2z = -x^2$$

Then, solving this according to the method for a first-order homogeneous equation

$$z = e^{-\frac{x^3}{3}}\left[-\int e^{\frac{x^3}{3}}x^2dx + c\right]$$

and substituting $z = 1/(y - y_1)$ gives the solution as

$$y = x - \frac{e^{\frac{x^3}{3}}}{\int e^{\frac{x^3}{3}}x^2dx + c}$$

Another special solution can be used for first order, homogeneous differential equations of any degree, linear or nonlinear. The general form is

$$F_1(x,y)dx + F_2(x,y)dy = 0$$

where functions F_1 and F_2 are both of the same degree. Because the degree of

YOUR TURN *continued*

these functions is the same, this special equation can always be written in the form

$$\frac{dy}{dx} = F_2\left(\frac{y}{x}\right)$$

Substituting $y/x = v$ and $dy = vdx + xdv$, changes the equation to

$$\frac{dx}{x} = \frac{dv}{F(v) - v}$$

which can be integrated to obtain the solution.

Example: The equation

$$(x^2 - xy)y' + y^2 = 0$$

is seen to be of the form of the general equation where $F_1(x,y) = y^2$ and $F_2(x,y) = x^2 - xy$. Substituting $y = xv$, $y^2 = x^2 v^2$, and $dy = vdx + xdv$ gives

$$\frac{dx}{x} = \frac{(v-1)\,dv}{v}$$

The general solution in terms of x and v is: $\ln x = v - \ln v + c$

or, in terms of x and y: $\ln y = \frac{y}{x} + c$

Now you try

Try your hand at these two special equations. Answers are on p 136.

1. $\frac{dy}{dx} = \frac{x-y}{x+y}$
2. $y' = (2x - x^4) + y^2$ (substitute $y_1 = x^2$)

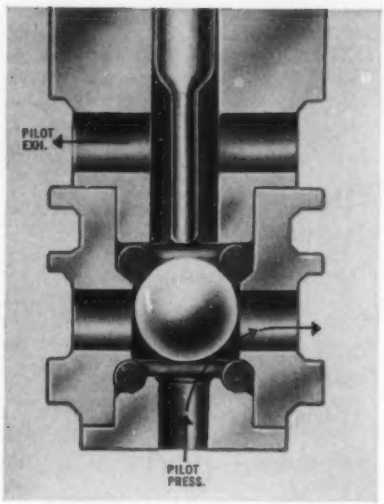
• • • •

Estimating sheet-metal blank-sizes for various circular shapes is not, normally, a design engineer's job. But sometimes it can be important to have this information in the early stages of a design—before it gets to the tool engineer. So to save your time, Your Turn has tabulated some handy formulas for . . .

. . . areas and blank diameters of circular shapes.

Shape	Area, A	Blank Diameter
Cone	$A=\frac{\pi}{4}d\sqrt{d^2+4h^2}=\frac{\pi}{2}df$	$D=\sqrt{d\sqrt{d^2+4h^2}}=\sqrt{2df}$
Frustrum	$A=\frac{\pi}{4}(d+d_1)\sqrt{(d-d_1)^2+4h^2}$ $=\frac{\pi}{2}f(d+d_1)$	$D=\sqrt{(d+d_1)\sqrt{(d-d_1)^2+4h^2}}$ $\sqrt{2f(d+d_1)}$
Sphere	$A=\pi d^2$	$D=2d$
Half-sphere	$A=\frac{\pi}{2}d^2$	$D=d\sqrt{2}$
Spherical segment	$A=\pi dh=\pi(r^2+r^2)$	$D=2\sqrt{dh}=2\sqrt{r^2+h^2}$
Spherical zone	$A=\pi dh$ $=\pi\sqrt{4r^2h^2+(r^2-r_1^2-h^2)^2}$	$D=2\sqrt{dh}$ $=2\sqrt[4]{4r^2h^2+(r^2-r_1^2-h^2)^2}$
Concave ring (quarter)	$A=\frac{\pi}{2}(\pi dr+4r^2)$	$D=\sqrt{2\pi dr+8r^2}$
Convex ring (quarter)	$A=\frac{\pi}{2}(\pi rd-4r^2)$	$D=\sqrt{2\pi rd-8r^2}$
Concave ring	$A=\pi\left[(d-2r)f+2rh\right]$	$D=2\sqrt{(d-2r)f+2rh}$
Convex ring	$A=\pi\left[(d+2r)f-2rh\right]$	$D=2\sqrt{(d+2r)f-2rh}$

How To Build An Air Valve That Beats Friction and Coil Heat



ENLARGED SECTION OF PILOT CARTRIDGE

To Achieve Endurance, a Breakthrough in Speed

Generally, the most unpredictable factor in solenoid valve life is the solenoid coil itself, and yet, a solenoid can be made to last practically forever if the coil can be kept from overheating. Coil heat is generated by long plunger travel and accelerated by erratic drag (friction) during that travel. Achieve a short, quick, sure plunger stroke and the coil will last indefinitely. Therefore, the life of a solenoid pilot air valve is directly related to speed of operation. To achieve operating speed, friction in the pilot section and solenoid plunger travel must be reduced to a minimum. Solve these problems and you get air control reliability that seems to have no limit.

The Call-Outs Tell the Story of Endurance

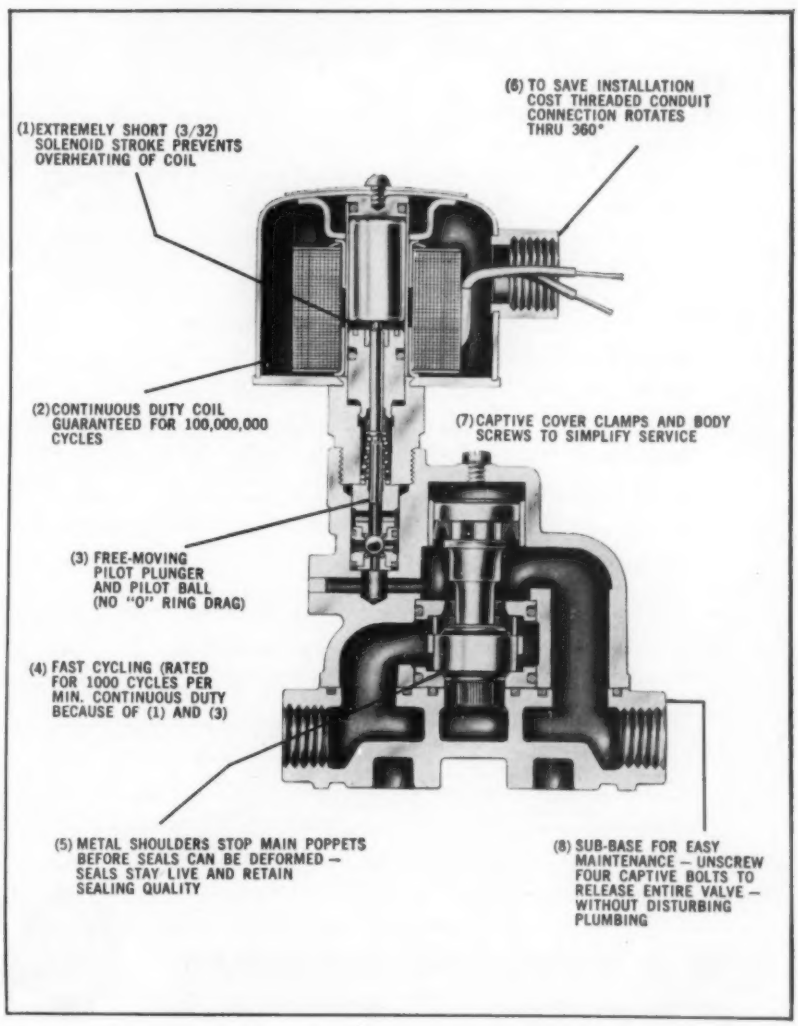
To control the major source of coil burnout, coil heating, the stroke of the solenoid plunger must be reduced to a minimum. The short stroke fractions the time the coil is energized; heat generation drops and response time of the valve is stepped up. In the "Mach 2" the stroke has been reduced to 3/32—about the thickness of a nickel. Furthermore, the friction problem must be solved, to avoid any unpredictable drag. In the "Mach 2" this has been done by use of a pilot cartridge enclosing a free-moving ball that seats on "O" rings at both ends of the cartridge [see above]. The ball moves freely, independent of the seals. There is no "O" ring drag on the pilot plunger as it requires no seals. When there is no friction there is no wear. Similarly, the main valve seats seal on "O" rings. In the sealed position, metal shoulders take the shock in such a way that the "O" ring seal is merely kissed by the main valve seat [see (5) below]. As the rings are only minutely flexed they do not fatigue or lose their resilience.

What about Cycling Speed?

Short solenoid plunger stroke and elimination of friction make extremely fast cycling feasible. After exhaustive testing in the laboratory and on industrial applications for over six years the "Mach 2" is rated at 1000 cycles per minute continuous duty. Cycling speeds as high as 2100 have been successfully reached for intermittent periods of twenty minutes. During a two-hour test at a sustained speed of over 1500 cycles per minute the coil temperature stabilized at 7°C below the maximum code limit for Class A coils.

100-Million-Cycle Guarantee on Solenoid Coils

The design advances incorporated in the CRESCENT® "Mach 2" Air Valve are a significant breakthrough in both cycling speed and operating dependability. Put CRESCENT® "Mach 2's" (¼- to ¾-inch pipe sizes) on your "valve killer" jobs and see how freedom from coil burnout helps to cut operating costs. Write for an advance copy of the new CRESCENT® "Mach 2" catalog to Barksdale Valves, 5125 Alcoa Avenue, Los Angeles 58, Calif.


(1) EXTREMELY SHORT (3/32) SOLENOID STROKE PREVENTS OVERHEATING OF COIL
(2) CONTINUOUS DUTY COIL GUARANTEED FOR 100,000,000 CYCLES
(3) FREE-MOVING PILOT PLUNGER AND PILOT BALL (NO "O" RING DRAG)
(4) FAST CYCLING (RATED FOR 1000 CYCLES PER MIN. CONTINUOUS DUTY BECAUSE OF (1) AND (3)
(5) METAL SHOULDERS STOP MAIN POPPETS BEFORE SEALS CAN BE DEFORMED — SEALS STAY LIVE AND RETAIN SEALING QUALITY
(6) TO SAVE INSTALLATION COST THREADED CONDUIT CONNECTION ROTATES THRU 360°
(7) CAPTIVE COVER CLAMPS AND BODY SCREWS TO SIMPLIFY SERVICE
(8) SUB-BASE FOR EASY MAINTENANCE — UNSCREW FOUR CAPTIVE BOLTS TO RELEASE ENTIRE VALVE — WITHOUT DISTURBING PLUMBING

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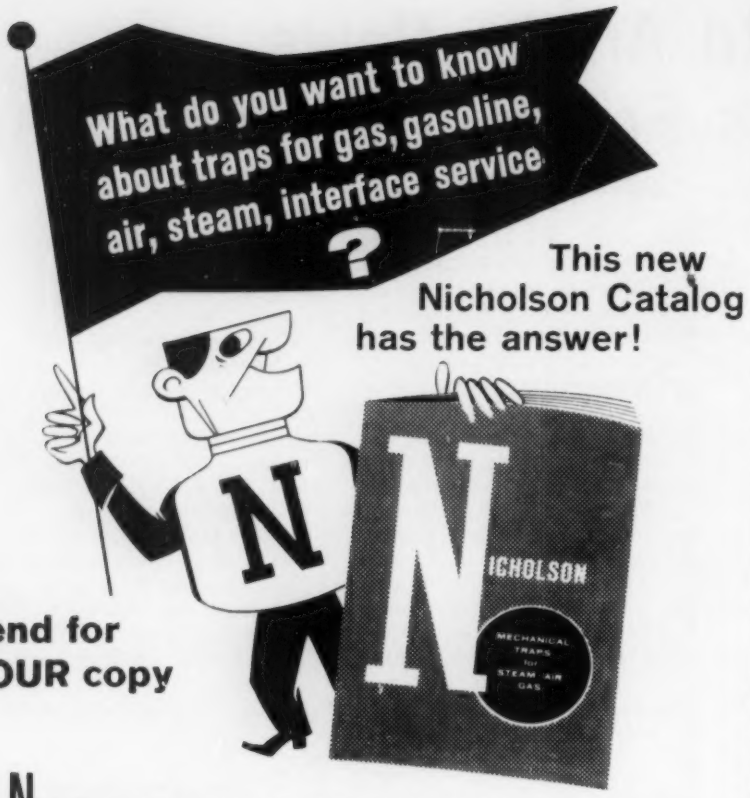
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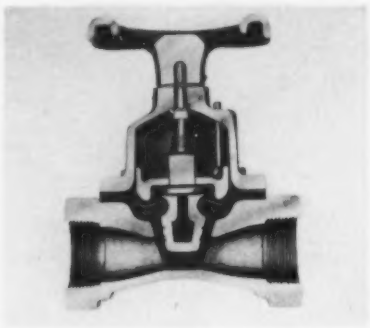

Straight-flow diaphragm valve . . . will handle gases, liquids, vacuums and slurries up to 180 F and to 150 psig, depending on size and choice of materials. Valve design is based on a metal wedge plug, to which rubber and fabric diaphragm is molded. Opening valve raises plug, which provides variable throttling in semi-venturi valve body. Available sizes range from ⅜ to 8 in. dia, in stainless, carbon steel, aluminum, bronze, and with or without glass, rubber or other special linings. Diaphragms can be supplied in a variety of polymers or other compounds. **Ohio Rubber Co—Cryogenics Corp, Willoughby, Ohio.**

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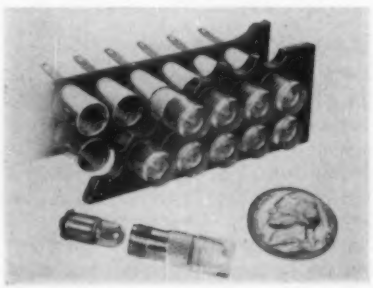
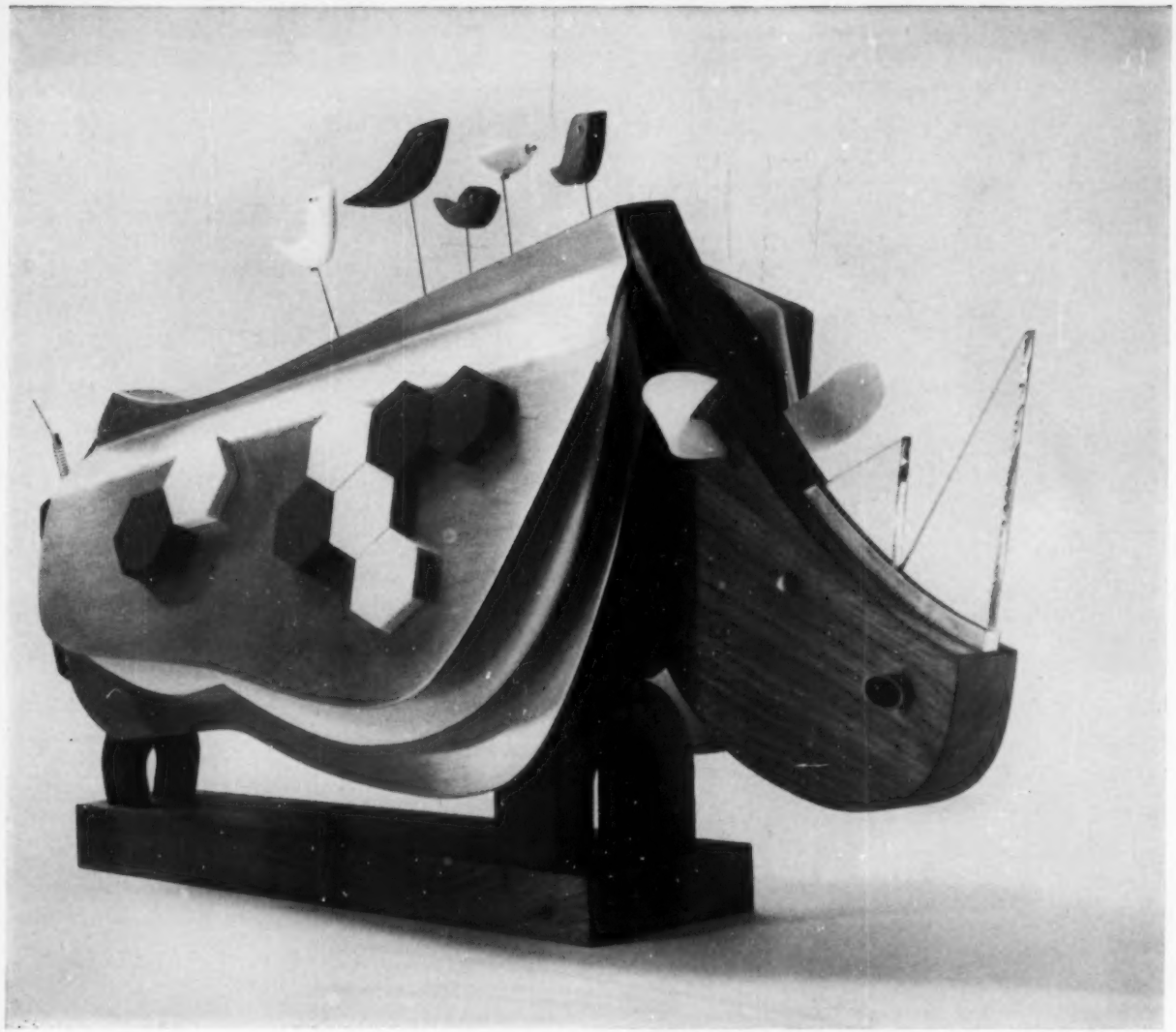


Close-mounting lamp assembly . . . consists of thermal strips and lamp sockets with integral standoffs that can be grouped on horizontal and vertical centers as close as ⅜ in. Lamps are miniature flange-base neon or incandescent types, available in twelve lens colors, transparent or

continued, page 116



Sculpture created especially for 3M Company by Guy Palazzola

STRENGTH

. . . Bonds "strong as a bull rhinoceros" made with SCOTCH-WELD® Brand Structural Adhesives

Whatever materials you're bonding (to the same or to another material), a SCOTCH-WELD Brand Structural Adhesive bond will give you a bonus of structural strength at the joint, with the flexibility to resist vibrational fatigue. SCOTCH-WELD adhesive bonds distribute stress loads uniformly, and protect the strength and integrity of the materials by eliminating fastening holes, maintaining the finish, and sealing joints against corrosion.

Fatigue tests show that metal-to-metal joints in Convair's 880 jet transports and Air Force F-102A jet interceptors, bonded with SCOTCH-WELD adhesives, will outlast the metal structure they bond together! In industry, too, SCOTCH-WELD adhesives are finding use in joining hermetically sealed metal shipping containers, multiple piece castings and thinner gauge metals, where tear strength would limit the effectiveness of other joining methods.

Look first to 3M! A pioneer in adhesive research, 3M has developed the widest line of adhesives in the industry. These Technical Service facilities are at your disposal. For an accurate appraisal of how an adhesive can add strength, light weight, production economy, and greater design freedom to your process or product, call your nearest 3M Field Engineer or write to: AC&S Division, 3M Company, Department SBS-111, St. Paul 6, Minnesota.

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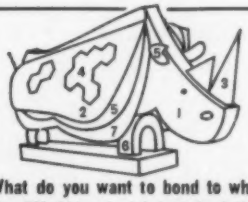

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1. Wood 2. Aluminum 3. Glass 4. Ceramic 5. Plastic 6. Permanent Magnet 7. Brass

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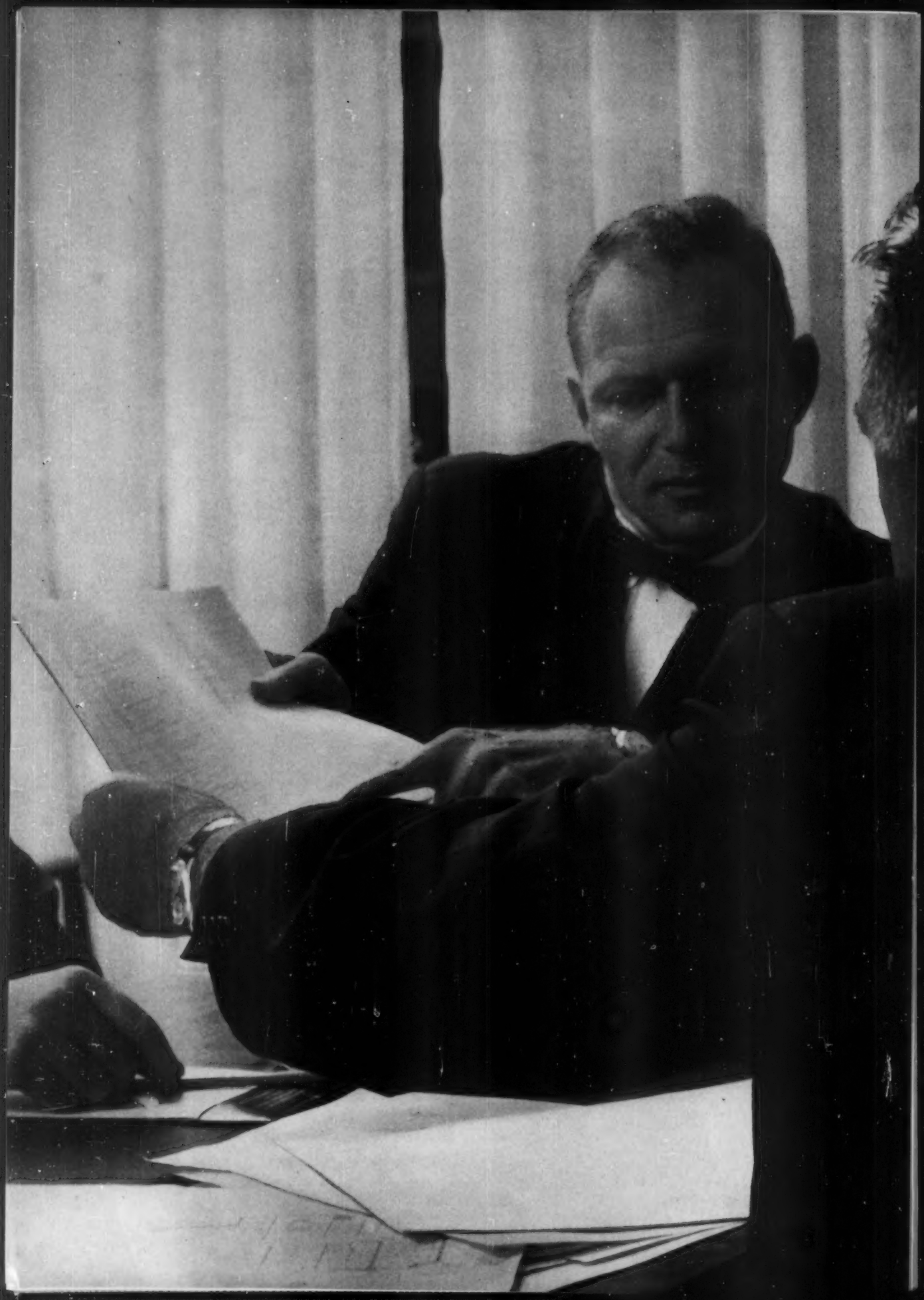
MINNESOTA MINING AND MANUFACTURING COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY



"Bob, the computer analysis says we should buy those parts instead of making them"

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SPECIAL PURPOSE PUMPS FOR SPECIAL PROBLEMS

► In over thirty years experience in the design and manufacture of special pumps, we have solved numerous pumping problems where the design and production of a suitable pump was considered almost impossible, either because of the material to be pumped, or because of the precise manufacture necessary to obtain satisfactory performance.

► **Nichols pumps are standard for example, in the synthetic fibre industry for pumping rayon, acetate, celanese, nylon and other fibres spun in synthetic fibre plants throughout the world.**

► Some interesting new applications for Gerotor pumps have been developed in recent times involving specialized problems in hydraulic servo systems.

► **Important advantages are offered by the Gerotor pump for servo control applications. It is a positive displacement pump and provides a smooth power flow from one end of the pumping cycle to the other. Unlike other types of pumps which tend to quit work at the low end of the speed range,** *Gerotors stay right on the job and provide positive power to the extremely low range.* **Thus, they are exceptionally responsive in servo systems.**

► For electronic equipment operating at high altitudes, air cooling of high input components becomes troublesome because lower air density limits cooling fan efficiency. Liquid cooling systems are therefore frequently preferred for this type of service. Our extensive experience over the years in the production of high performance aircraft engine pumps has been of great value in developing electronic coolant circulators that provide maximum weight and space savings with efficient heat transfer capabilities.

► **Special pumps have been designed and manufactured for applications as varied as metering pumps in vending machines and conveying molten solder in production equipment. This long and varied experience in industry-wide pumping applications, combined with years of specialized development and production of pumps for the aircraft engine, super-charger, missile, helicopter and electronic field is available to today's designer faced with new and unusual pumping applications and problems.**

► *Technical data is available and your inquiry is invited. Write:*

W. H. NICHOLS CO.

Makers of Zenith Metering Pumps
and the Nichols Milling Machine
"the miller that uses its head".

48 WOERD AVE., WALTHAM 54, MASS.

translucent, flat top or an optional water-tight (on panel side) design. Tinned terminals accept series 78 taper tab receptacles or soldering. Back panel projection is approx 1 in. **Teclite Div, Transistor Electronics Corp, 3357 Republic Ave, Minneapolis 26, Minn.**

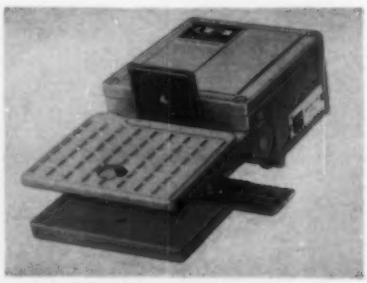
CIRCLE 321 ON READER SERVICE CARD

Weld nuts . . .
that are said not to require retapping are available in two configurations: Model SL has self-locating pilot and is designed for single spotweld at one end, with threads at opposite end of nut. Model S2 requires double spot weld and has threads located in center. Both styles are made in low carbon steel, are available from stock in all standard sizes. **Grip Nut Co, Sub Heli-Coil Corp, S Whitly, Ind.**

CIRCLE 322 ON READER SERVICE CARD

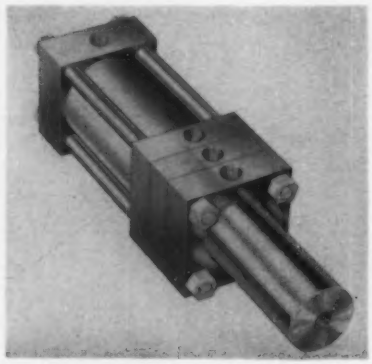
Subminiature limit stops . . .
are made in BUORD sizes 5 and 8 designed for 0-10 turns and 0-40 turns, respectively. Mounting plates are of BUORD servo type and are made of stainless. Shafts are hardened and ground, traveling nuts are phosphor bronze. Torque rating on size 5 is 50 in.-oz; on size 8, 160 in.-oz. **Northfield Precision Instrument Corp, Island Park, NY**

CIRCLE 323 ON READER SERVICE CARD



Variable foot switch . . .
has two unit switches, one with normally open and the other with normally closed contact arrangement. Adjustable steel lever assembly can be set to provide simultaneous or sequential operation, or differential tripping for second stage operation. Light, medium or heavy second stage feel springs are available that help operator to sense differential between first and second stage actuation. These springs can be changed in service. A treadle latch is also obtainable that converts foot switch from spring return to maintain contact. Enclosures are NEMA 4 watertight, but NEMA 7 and 9 enclosures are also available. Plain, treadle guard and treadle shield covers can be specified for various degrees of protection from accidental actuation. **Cutler-Hammer, 318 N 12th St, Milwaukee 1.**

CIRCLE 324 ON READER SERVICE CARD



Booster cylinders . . .
for hydraulic systems operate with normal shop air pressures. Two series are available, with capacities of 150 psi air; or 5000 psi hydraulic. Bore sizes of these cylinders range from 1-½ to 14 in. **Milwaukee Cylinder Co, Cudahy, Wis.**

CIRCLE 325 ON READER SERVICE CARD

AC multi-pole latch relays . . .
are for machine tool and other control applications where circuits must function independently of circuit or power failure. Also recommended where noise caused by normal ac hum or vibration is not permissible. Available with 2, 3, 4 or 6 normally open or normally closed unit poles. Obtainable with standard coils to 220 v, 60 cps ac. **Ward Leonard Electric Co, Mt Vernon, NY.**

CIRCLE 326 ON READER SERVICE CARD

Counter assembly . . .
has digits 0.420 in. high arranged on drums 1-7/16 in. dia and is reversible. Drums and pinions are nylon, shafts are stainless, in nickel silver frame. Available with oilite or ball bearings. Designed for direct readout applications replacing pointer dials. **Haydon Instrument Co, 17 Brown St, Waterbury 20, Conn.**

CIRCLE 327 ON READER SERVICE CARD

Linde Coatings & materials News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Long wear for precision cutting parts now comes in thin coatings—.001" thick

Two important industrial cutting tools whose working lives have been multiplied by LINDE Flame-Plating tungsten carbide coatings: Rubber skiving knives (l.) and paper drills.

SUPER-THIN coatings of tungsten carbide and aluminum oxide—in the .00075" to .002" range of thickness—now keep many industrial cutting surfaces on the job many times longer than previously, yet preserve the precision fit needed for optimum cutting. The result: important savings in downtime and operating costs.

These tough, long-life precision coatings are applied by LINDE's Flame-Plating process, which "blasts" molten particles of tungsten carbide onto specified areas of wearing surfaces until the particles are built up to the desired degree of thickness.

Typical examples of longer wear

Because their cutting surfaces are Flame-Plated with tungsten carbide coating, rubber skiving knives that formerly required resharpening after every shift now stay in use 15 times longer. The knives also have the advantage of a self-sharpening effect. As the softer steel base wears more rapidly than the hard, tungsten carbide coating, a sharp edge is always presented to the material being cut.

Tungsten carbide coating enables serrated knives used in cutting plastic sheeting to process three times as much material before the first re-sharpening is necessary.

A coating of .001" thickness on the inside cutting surface of surgical shears has reduced their rate of wear by as much as 33 percent.

Flame-Plating proved so revolutionary for household cutlery that the manufacturer built his merchandising theme around *"The Greatest Development in 2000 Years of Cutlery Making—a Cutting Edge of Tungsten Carbide."*

Solves many wear problems

Tungsten carbide coatings of microinches thickness are equally effective wherever metal parts or working surfaces are exposed to abrasion, galling, erosion, fretting, corrosion, or high-temperature wear. Coatings are applied by the LINDE's 6,000-degree Flame-Plating process without distortion of the work piece or changes in properties of base metals.

For full information on Flame-Plating for your particular application, check and mail the coupon below.

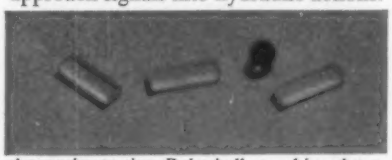
Need to production-polish tungsten carbide surfaces?

It's easy with LINDE metallographic production-polishing aluminas—available in grades for three types of finishing: For high stock removal, 1 micron C; for moderate stock removal and ¼ rms finish, 0.3 micron A; for super polish, 0.05 micron B.

LINDE has developed special techniques for production-polishing of semiconductors and soft metals (such as brass), also new ideas for production-polishing hard metals, including micrometer anvils, hardened bearing races, routine metallographic samples. Get help with polishing techniques to meet your requirements. Send coupon below.

Jet planes landed by ruby-against-sapphire wear pads

In the automatic landing computer of a modern jet interceptor, a tiny ruby ball held to tolerances of 30 millionths oscillates against a synthetic sapphire plate flat to 1/10 light band, as a reference plate for a computer to translate radar approach signals into hydraulic actions.



Approximate size: Ruby ball, sapphire plates.

A similar wear surface bears on the cam head. Certain fly wheel governors also have sapphire wear surfaces.

This 70,000 to 300,000 psi LINDE material has a hardness second only to diamond, unlubricated static friction coefficient of .18, and dynamic of .08 against itself in moderate loads. It is economically suited for wear applications such as gage points, textile guides, optical inspection flats, and flow valves. Send coupon for information.

CHECK—CLIP COUPON—ATTACH TO BUSINESS LETTERHEAD

Linde Company
270 Park Avenue
New York 17, N. Y.

Please send data on the items checked:

- ☐ LINDE Flame-Plating Process
- ☐ LINDE Alumina Abrasive Powders
- ☐ LINDE Synthetic Sapphire & Ruby

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LINDE COMPANY

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Fully automatic production is the key to better glass tube mercury switches. You can be sure of uniformity in dimension, mercury content and assembly of all parts when manufacture is under exacting automatic control. Mercury switches are ideal monitors for control of inductive and resistive electrical loads where requirements are long life and high electrical capacity. Since mercury switches are hermetically sealed, contacts can never become contaminated. They are available potted in resilient and protective material for applications where the going is rough.

For engineering service and assistance in application and selection of mercury or snap-action switches, contact a MICRO SWITCH branch office, listed in the Yellow Pages. Or write for Catalog 90.

MICRO SWITCH, FREEPORT, ILLINOIS
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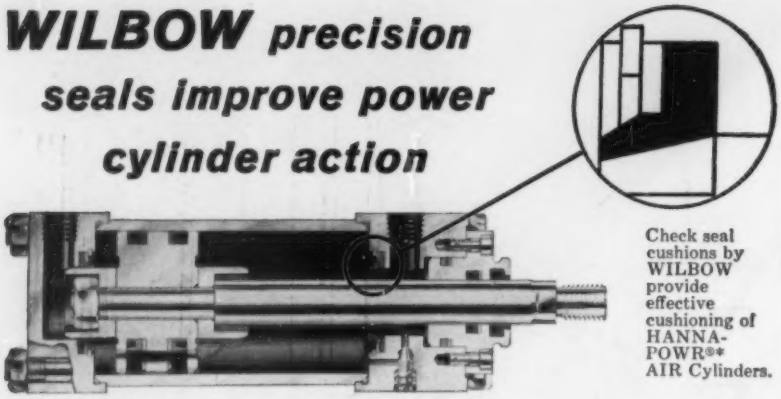
Honeywell
MICRO SWITCH Precision Switches

CIRCLE 119 ON READER SERVICE CARD

WILBOW precision seals improve power cylinder action



Check seal cushions by WILBOW provide effective cushioning of HANNA-POWR®* AIR Cylinders.

SEND FOR COMPLETE WILBOW CATALOG

Each cushion valve in The Hanna POWRMATION®* Cylinder shown above has been precision engineered and manufactured to stop heavy and fast moving loads without severe impact or bounce. Seals conform to high standards including excellent uniformity and long life—thanks to the special properties of the synthetic materials used and the manufacturing experience of WILBOW in producing custom rubber parts.

WILBOW specializes in the manufacture of precision mechanical rubber parts to meet the most rigid performance requirements. A full range of the newer synthetics, natural or silicone polymers plus the broadest production versatility . . . including molding, lathe cutting, extruding or punching . . . is at your service. Why not check *your* needs with WILBOW?

Wilbow

*HANNA-POWR and POWRMATION are registered trademarks of Hanna Engineering Works, Chicago, Ill.

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IF YOU NEED A MINIATURE VALVE YOU NEED . . .

The New and Unique MICRO VALVE®

NO MAINTENANCE AFTER MILLIONS OF OPERATIONS

- Instantaneous Response with no Intermediate Position
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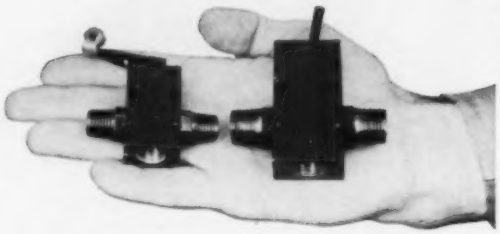
- Dimensions: as small as ⅝" x 1½" x 1¾"
- Weight: As light as 2 oz.
- For Pressure or Vacuum Service



The Micro Valve is offered in hundreds of variations. The two shown above feature male pipe connections which rotate on the body permitting installation without the added expense of unions.

INSTRUMENTS, INC.

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WHOLLY OWNED SUBSIDIARY OF NATIONAL TANK COMPANY

For Additional Information Write For Bulletin MV-459

NEW MATERIALS

Low-density silicone foam . . . is supplied as low-viscosity fluid, addition of catalyst producing foam. Sevenfold increase in volume is said to be completed in 4-5 min. at room temperature. Foam has 10% closed cell structure and density of 10 lb/cu ft. Serviceable from —70 to 500 F. **Dow Corning Corp, Midland, Mich.**

CIRCLE 328 ON READER SERVICE CARD

Vacuum-deposited metal films . . . of a few millionths of an inch in thickness and controlled within ±5%, can be applied to metallic, glass, plastic or ceramic surfaces. Gold, copper, chromium and many other metals, as well as their alloys, can be deposited on areas up to 48 x 48 in. **Evaporated Coatings, Inc, Huntingdon Valley, Penna.**

CIRCLE 329 ON READER SERVICE CARD

Adhesive film . . . provides bonds of 1000-1500 psi, requiring processing temperatures of 150-200 F for 5-10 sec with standard squeeze-roll pressures. Will withstand temperatures from —60 F to 150 F, with intermittent exposures to 200 F. Resists shock, moisture, solvent vapors, moderate oil and solvent exposure. **Girder Process Inc, 102 PT Hobart St, Hackensack, NJ**

CIRCLE 330 ON READER SERVICE CARD

Electrohydraulic forming . . . system performs metalworking operations now done on heavy press equipment. Recommended for forming metals difficult to work by conventional means because of work hardening or other such problems. Can make shapes difficult or impossible to achieve by conventional methods. Permits use of plastic or wooden dies, on which quick, experimental modifications can be made. Consists of a bank of low-inductance energy-storing capacitors, control system, d-c power supply. **Westinghouse Electric Corp, PO Box 2099, Pittsburgh 30.**

CIRCLE 331 ON READER SERVICE CARD

Monel metal powder parts . . . with nominal composition of 67 nickel, 30 copper, bal of iron, manganese and silicon, average 30,000 psi

continued, page 127

One in a series of technical reports by Bower

BEARING BRIEFINGS

TESTING PUTS THE HEAT ON—HELPS BEARINGS BEHAVE IN EXTREME ENVIRONMENTS

In industry today, bearing operating conditions are becoming increasingly severe. To conquer difficult environments, heat, corrosion and oxidation, Bower conducts exhaustive research to achieve improved bearing performance. One important area of Bower research, for example, is the development of special alloys to withstand extreme heat. To do this, Bower researchers use special heating apparatus to study hardness, strength and other characteristics of alloys at temperatures in excess of 1000°F.

One of the devices Bower utilizes to assure bearing precision at high temperatures is a creep tester. Bower engineers use it to load a test bar to a predetermined stress level, then, with the assistance of a special heating unit, find out precisely how much the bar stretches as temperatures are elevated to a thousand degrees F., and beyond.

With this type of data and the help of other Bower precision research equipment, engineers can determine alloys that best withstand torrid temperatures. They can also effectively mate thermal expansion characteristics of the various alloys used in roller bearing components and in shafts and housings as well. As a result of this mating, Bower creates bearings that maintain precision in the required temperature ranges and ensures bearings that provide long life, heavy load capacity and high-speed operation.

Because of Bower's continuing research in bearing alloys and other critical areas, we suggest you consider Bower to assist you with your bearing needs. Bower provides a full range of types and sizes in tapered and cylindrical roller bearings as well as in journal roller assemblies. Bower Roller Bearing Division, Detroit 14, Michigan.

Bower engineers study how alloys stretch as temperatures rise in excess of 1000°F., to perfect bearings that can take it.

BOWER ROLLER BEARINGS

tapered cylindrical journal

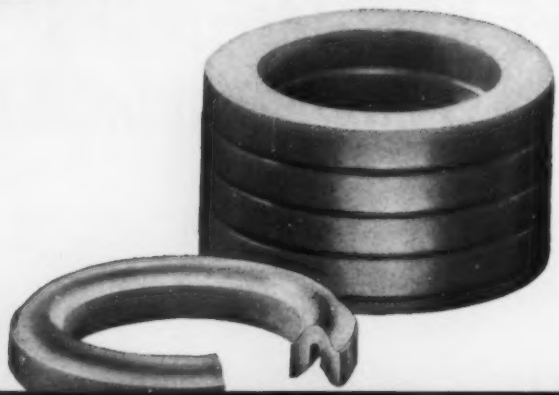
DIVISION OF FEDERAL-MOGUL-BOWER BEARINGS, INC.

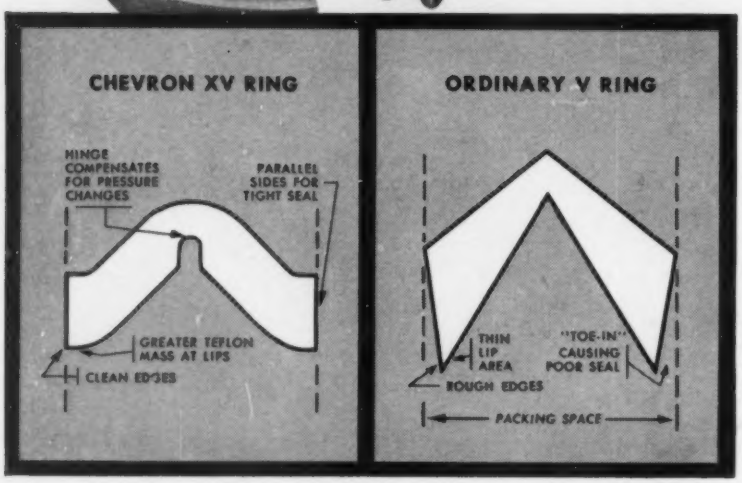
CIRCLE 121 ON READER SERVICE CARD

NEW

GARLOCK CHEVRON* XV TEFLON† PACKING

for Hydraulic, Pneumatic Service





A new high in V-ring performance and efficiency is here from Garlock in the new CHEVRON XV Teflon Packings. Used for valves, pumps and instruments in corrosive service, this exclusive Garlock design has outperformed ordinary Teflon V-rings in rigid controlled tests. CHEVRON XV is superior in flexibility, freedom from friction, wear resistance and sealing efficiency under varying pressures—withstands pressures to 1000 p.s.i. (rings without hinges available for pressures above 1000 p.s.i.).

Can be molded precisely. The greater material mass of CHEVRON XV permits molding to consistent close tolerances ring after ring—batch after batch. Result—perfect fit, clean lips, far better sealing.

Ends frequent gland adjustment. The exclusive CHEVRON hinge compensates for pressure changes automatically. With proper installation, further adjustments are eliminated.

Greatly extends wear. Greater material mass and parallel sides give Garlock CHEVRON XV PACKINGS much more working Teflon than ordinary V-rings. Sturdier size for size, they wear considerably longer . . . yet cost you no more.

Virtually ends friction because of two factors. First, Teflon has the lowest coefficient of breakaway and running friction of any solid material in use today. Second, the exclusive CHEVRON hinge action permits free operation with minimum friction at all pressures.

Learn the full story of this superior new packing. Discuss your particular needs with your Garlock representative. Call him at the nearest of 26 Garlock sales offices and warehouses throughout the U.S. and Canada. Or, write for Catalog AD-192, Garlock Inc., Palmyra, New York.

GARLOCK

Canadian Div.: Garlock of Canada Ltd.

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Order from the complete line of quality Garlock products . . . Packings, Gaskets, Seals, Molded and Extruded Rubber, Plastic Stock and Parts.

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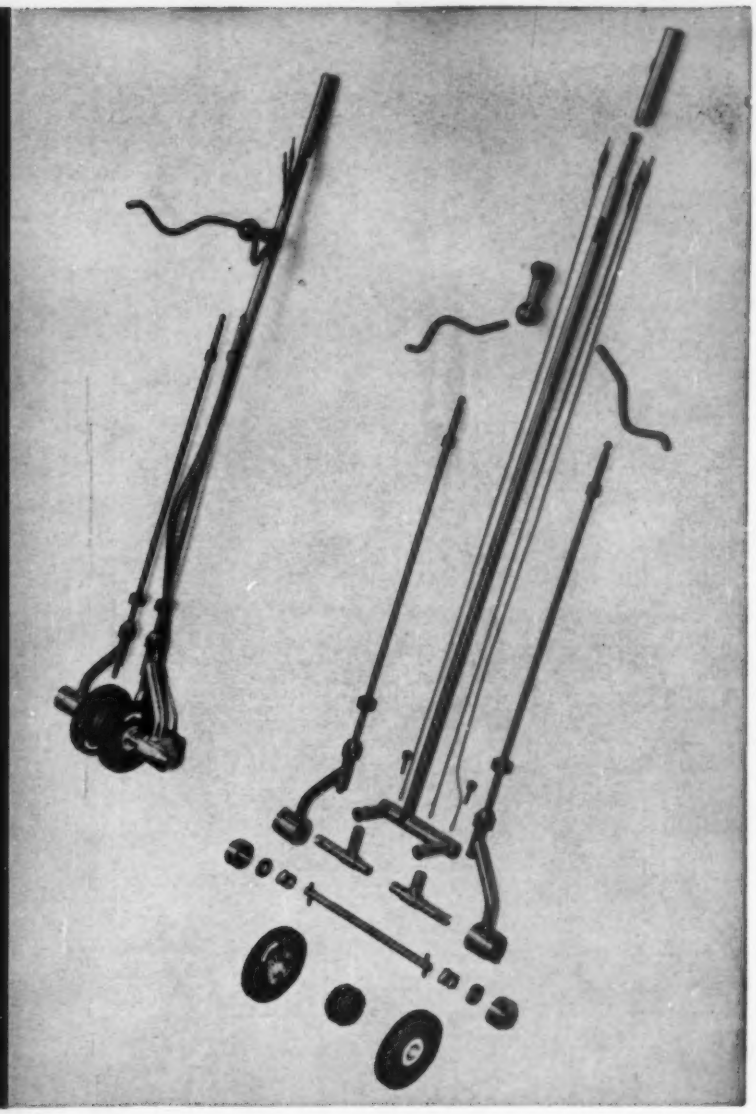
HERE'S HOW STILL ANOTHER MANUFACTURER JOINS STAINLESS STEEL TUBING:

He uses Handy & Harman's BRAZE 630



He's one of many manufacturers and fabricators who have found—to their lasting satisfaction—that Handy & Harman silver alloy brazing is the final answer to stainless steel joining problems.

Super-Donic Manufacturing Company, Atlanta, Georgia, manufactures "Dual Arm Transmissions" for the dental industry. Most everybody has—at one time or another—seen and/or felt this unit in operation.

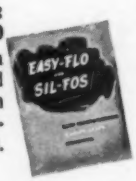
It is fabricated of small diameter 304 and 316 stainless steel tubing and, in its assembled form, consists of some 17 separate brazed joints. Joints must be strong, corrosion resistant and neat-appearing.

Each of the 17 joints is hand-torch brazed with Handy & Harman BRAZE 630 wire and HANDY FLUX TYPE B-1. There's no question that this is a unique application. There's no question, either, that the application is stainless steel. The ease and economy with which this manufacturer solves his problems can be just as readily applied to *your* stainless steel joining problems.

Strength, production speed, electrical and thermal conductivity, gas and liquid tightness and low cost are *natural* benefits of silver alloy brazing. We think it worth your while to learn more about this remarkable metal-joining method—we'll be glad to send you any information you ask for. Handy & Harman, 850 Third Ave., New York 22, N. Y.

FOR A GOOD START: BULLETIN 20

This informative booklet gives a good picture of silver brazing and its benefits... includes details on alloys, heating methods, joint design and production techniques. Write for your copy.



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CIRCLE 123 ON READER SERVICE CARD 123

"I don't know who you are.

I don't know your company.

I don't know your company's product.

I don't know what your company stands for.

I don't know your company's customers.

I don't know your company's record.

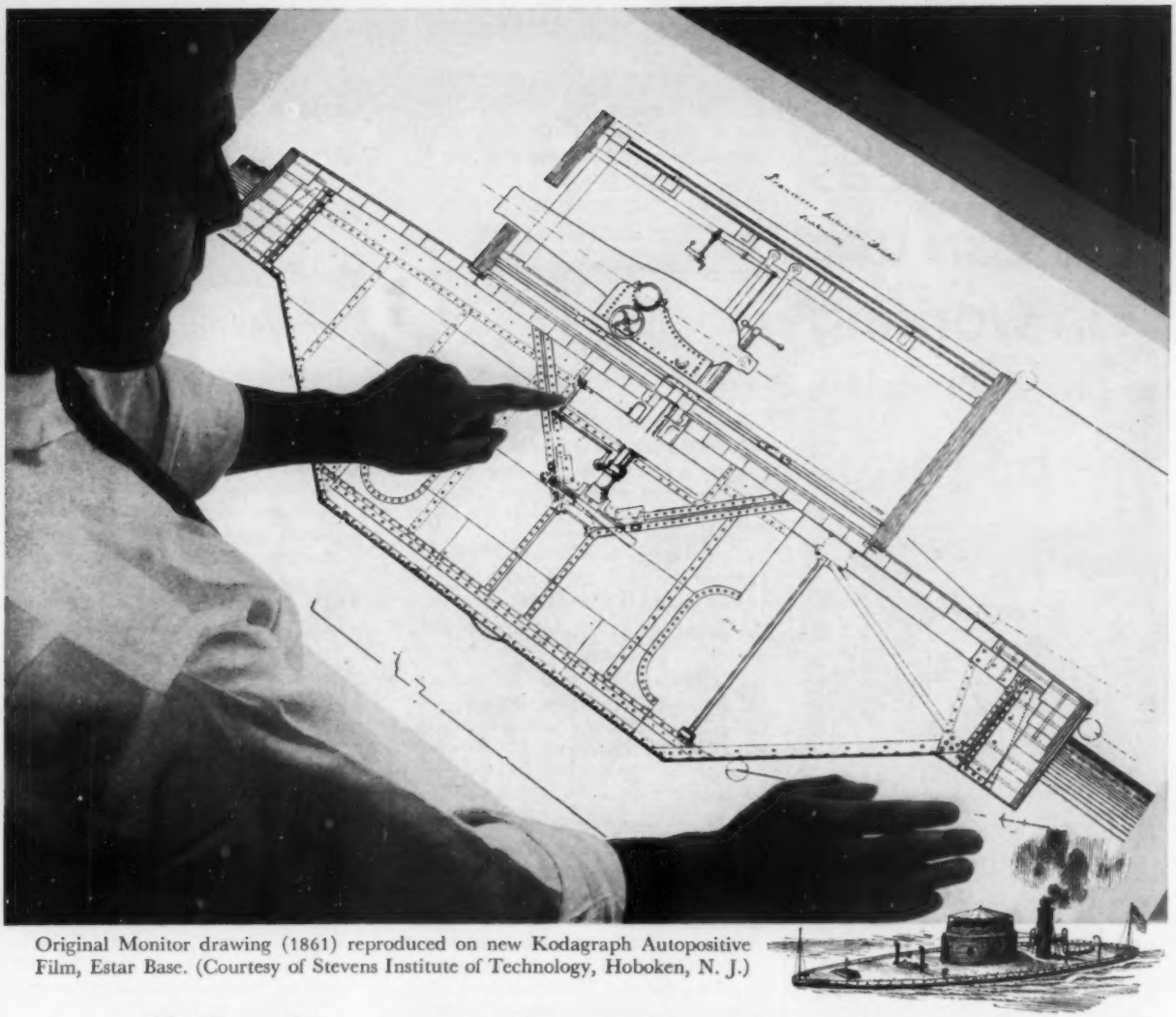
I don't know your company's reputation.

Now—what was it you wanted to sell me?"

MORAL:
Sales start before your salesman calls—with business publication advertising.

McGraw-Hill
PUBLICATIONS

McGRAW-HILL PUBLISHING COMPANY, INC., 330 WEST 42nd STREET, NEW YORK 36, N. Y.



Original Monitor drawing (1861) reproduced on new Kodagraph Autopositive Film, Estar Base. (Courtesy of Stevens Institute of Technology, Hoboken, N. J.)

Made to take the bruises!

New Kodagraph Autopositive Film, Estar Base, gives you intermediates that are as tough as they come and have exceptionally sharp detail.

Here's the ideal choice for general reproduction work and drafting-room use. Same-size, positive intermediates are produced directly without a negative step. And there's the added convenience of being able to expose and process under room light. Excellent results are obtained with either "print-through" or reflex printing, even when reflexing from metal templates.

See this versatile new Kodagraph Film—and the others in the new *Estar Base line:* Kodagraph Contact Film; Kodagraph Projection Film.

All combine reliable Kodak emulsions on the new Estar Base—highly translucent, durable, and dimensionally stable, with excellent matte surface on both sides for easy drafting. Available in standard drawing sheet sizes and in rolls up to 52 inches wide. Call your local Kodagraph Dealer, or write Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y.

NEW!
Kodagraph

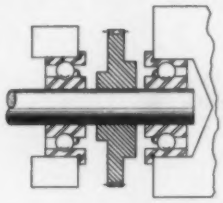
REPRODUCTION FILMS
for best line-for-line reproduction

Kodak

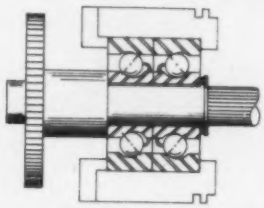
CIRCLE 125 ON READER SERVICE CARD 125

No. 3

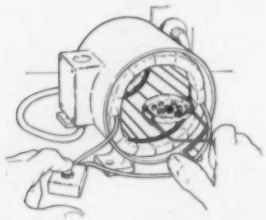
ideas you can use in working with bearings



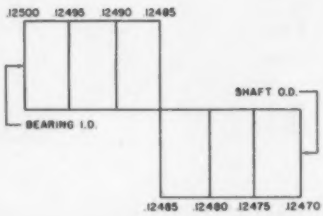
The use of flanged bearings can reduce expense in servomechanism gearing, especially where plate or cantilever construction is involved. The flange eliminates the need for bearing retainer plates and also makes it possible to blind depth bore to non-critical depths. The blind hole can be used as a lubricant reservoir to retain grease.



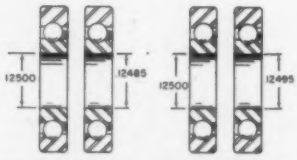
The output shaft bearings in gear heads are usually preloaded to reduce backlash. Pairs of bearings, preloaded to a specific value by the bearing manufacturer, offer two advantages. Variation in preloading during assembly is eliminated which means more consistent torque and end shake values from unit to unit. Secondly, assembly time is reduced. Where required, the advantages of preloaded bearings can justify their additional cost.



A bearing which has become magnetized will attract stray metallic particles which can work their way on to raceways or balls with disastrous effects on bearing performance. Although all New Hampshire bearings are carefully demagnetized before final washing and packaging, it is possible for them to be re-magnetized during shipment if they are placed in strong magnetic fields. A good precaution is to perform final demagnetization before installing bearings in their final assemblies.



Interference fitting tighter than line to line is not recommended by New Hampshire for the majority of applications. The block diagram above shows this fit achieved by coded selection. The bearing I.D. is represented by the top blocks and the shaft O.D. by the lower blocks. The bearing I.D. represents a tolerance of .00015" with a similar tolerance for the shaft. A resulting fit of line to line to .0003" loose is shown.



ABEC CLASS 7 BEARINGS WITH STANDARD BORE TOLERANCES OF .00015" AT EXTREMES OF BORE TOLERANCE

ABEC CLASS 7 BEARINGS WITH BORES CODED IN .000050" INCREMENTS AT EXTREMES OF BORE TOLERANCE.

In high accuracy designs where bearings must be as close together as possible (e.g. bevel gear differentials) shaft to inner race fit is vitally important to assure as much radial stability as possible under these conditions. Even two ABEC Class 7 bearings would not provide a sufficiently precise fit should their bores be at the extremes of tolerance (.00015"). However, bearings may be specified with bores coded in .000050" increments.

150-page Design and Purchasing Manual is the most comprehensive treatise on miniature and instrument ball bearings ever published. Qualified design and specifications engineers, and procurement specialists, are welcome to a copy.

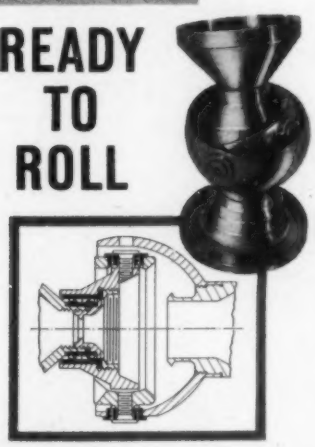
NHBB FLANGED RETAINER BEARINGS							
BORE	O.D.	WIDTH	BEARING NUMBER	FLANGE DIAMETER	FLANGE WIDTH	RADIUS	C RATING
.0469	.1562	.0625	SFR0	.203	.013	.005	19
.0550	.1875	.0781	SFR1	.234	.023	.005	28
.0781	.2500	.0937	SFR1-4	.296	.023	.006	39
.0937	.1875	.0625	SFR133	.234	.018	.005	21
.0937	.3125	.1094	SFR1-5	.359	.023	.006	64
.1250	.2500	.0937	SFR144	.296	.023	.005	36
.1250	.3125	.1094	SFR2-5	.359	.023	.006	66
.1250	.3750	.1094	SFR2-6	.422	.023	.006	66
.1250	.3750	.1562	SFR2	.440	.030	.012	73
.1562	.3125	.1094	SFR155	.359	.023	.005	35
.1875	.3125	.1094	SFR156	.359	.023	.005	35
.1875	.3750	.1250	SFR166	.422	.023	.008	82
.1875	.5000	.1960	SFR3	.565	.042	.012	137
.2500	.3750	.1250	SFR168	.422	.023	.008	44
.2500	.5000	.1250	SFR188	.547	.023	.010	120
.2500	.6250	.1960	SFR4	.690	.042	.012	170
.3125	.5000	.1562	SFR1810	.547	.031	.009	60

NEW HAMPSHIRE BALL BEARINGS, INC.

PETERBOROUGH, N. H.

Instrument sub-assemblies complete with precision-fitted miniature or instrument ball bearings

READY TO ROLL



If you have a problem making or obtaining some of the proper components for instrument bearing sub-assemblies — or if you have trouble fitting them together with the required precision — you should investigate the services of the Rotassembly Division at New Hampshire.

In this separate facility, assemblies including bearings, shafts, housings and pulleys are produced to your designs, to New Hampshire precision standards and shipped to you inspected, tested and ready to install.

Manufacture is restricted to mechanical units in which the correct installation and performance of bearings are important and critical elements of the assembled unit. We are not manufacturers of or qualified to produce gears, gear trains, gear boxes, motors or electrical components.

For more complete information, write for Rotassembly Bulletin.

NEW HAMPSHIRE BALL BEARINGS, INC.
PETERBOROUGH, N. H.

tensile, at 7.2 g/cc density. Hardnesses range from 50 to 60 on 15T scale, and elongation is about 5%. Useful operating range of these metal powder components is to 1000F. Particularly recommended for corrosive applications. **US Graphite Co, Div Wickes Corp, Saginaw, Mich.**

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Pure cobalt strip . . . with good ductility and workability is supplied in coils with thickness ranging from 0.005 to 0.025 in., and widths of ¼ to 6 in. Rolled directly from cobalt powder, this process produces 99.9% pure cobalt strip, which has tensile strength of 164,000 psi when rolled to 25% reduction. Elongation is 0.5% and hardness 85 Rockwell (45T). In annealed condition, this same strip has tensile of 115,000 psi, elongation of 15% and hardness of 68. Base price, $4.40 per lb. **Sherritt Gordon Mines Ltd, 25 King St W, Toronto 1, Canada.**

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and CONTOUR MACHINED TO SPACE AGE TOLERANCES

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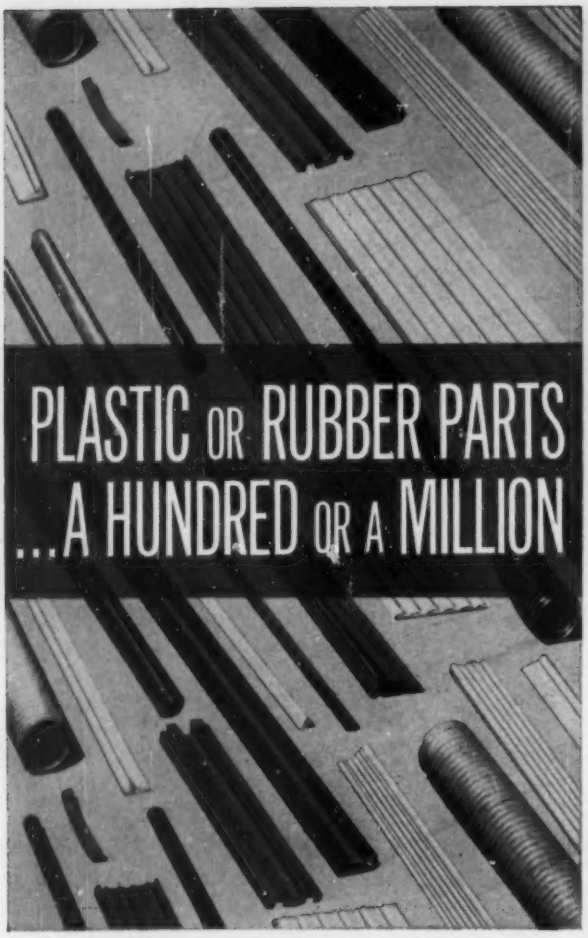

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CIRCLE 46 ON READER SERVICE CARD

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CIRCLE 336 ON READER SERVICE CARD

Air volume slide rule . . . figures standard cubic feet of air required for any pneumatic circuit, based on cylinders of any bore and stroke, at any pressure and time cycle. Determines air pressure for desired cylinder stroke speed, matches cylinder bore size to required force, gives min compression capacity system will need. Price $2; available from stock. **Flow Finder, Box 578, Westfield, NJ**

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Tape pen . . . applies self-sticking tapes to charts, printed circuit masters and other graphic illustrations. Curved or irregular lines from 1/32 to 1/8 in. wide can be made, reportedly accurate for placement to 0.010 in. Corrections and changes are made by lifting up misplaced tape and replacing it. Pen is operated by loading a roll of tape into the styrene magazine, pulling it through the inner shaft, replacing outer shaft, and dialing correct tape width on magazine hub. Wheel assembly at lower end of pen simultaneously feeds, applies and burnishes the tape. **W H Brady Co, Dept 169, 789 W Glendale Ave, Milwaukee 9.**

CIRCLE 338 ON READER SERVICE CARD

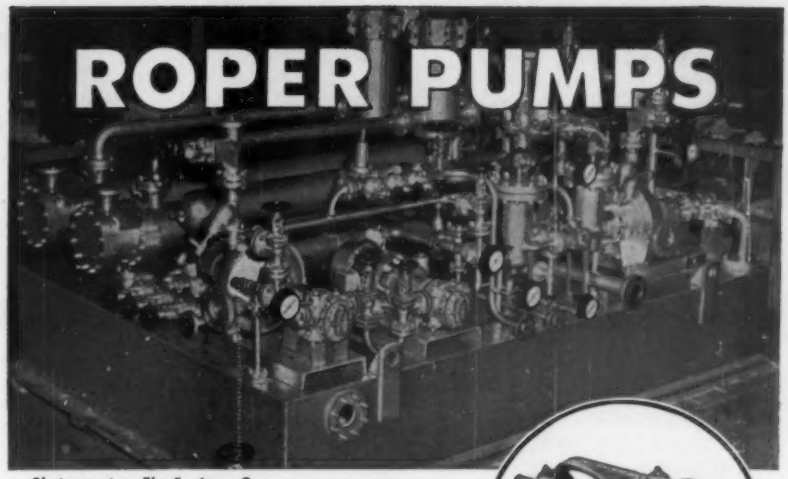

Photo courtesy The Engineer Co.

maintain lubrication of seals and oil bearings on large centrifugal compressor

• CAPACITY RANGE: 5-75 GPM • OPERATING PRESSURES: TO 1000 PSI

The complex lube system for this centrifugal compressor was designed by The Engineer Co. for the Elliott Co. and Blaw-Knox for Ashland Oil Co., using two types of Roper pumps as booster and main lube units. The Fig. 1H15 booster pumps handle 70 SSU viscosity SAE-10 lube oil at operating temperatures of 140°F, and deliver up to 17 gpm at 475 psi pressure. The two main lube pumps are specially modified Roper Series K units handling 76 gpm at 50 psi. Close cooperation with The Engineer Co. by Roper determined the pumps which would best serve the needs of this lubricating system. Special problems involving pump components for your equipment will receive this same skilled assistance by Roper engineers.

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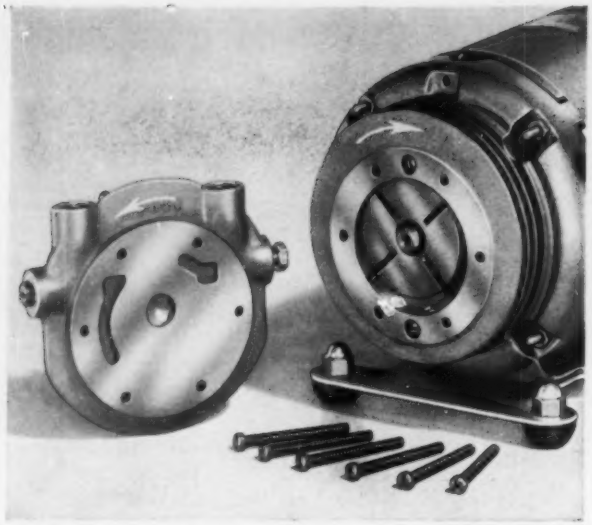

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You gain five advantages when you specify Gast Oil-less Air Compressors or Vacuum Pumps.

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3. Lubrication costs for both time and lubricants are eliminated.
4. You have greater freedom in locating the pump, as easy access for oiling isn't a factor.
5. Oil-less design adds a sales feature to your product!

How is this possible? Rotary design has carbon vanes that lubricate themselves. Ball bearings are grease-sealed for life and located outside the pumping chamber. Simple construction assures long, trouble-free dependability.

Ten sizes; capacities from .35 up to 24 c.f.m. running open. For medium duty to 10 p.s.i.g. pressure or 20" Hg vacuum. For use on instruments, medical and laboratory equipment, food packaging and paper-handling machines, Gast Oil-less Air Pumps have much to offer.

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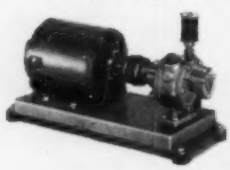
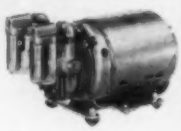
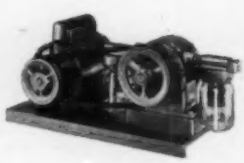


Integral-motor types to 1.1 c.f.m.





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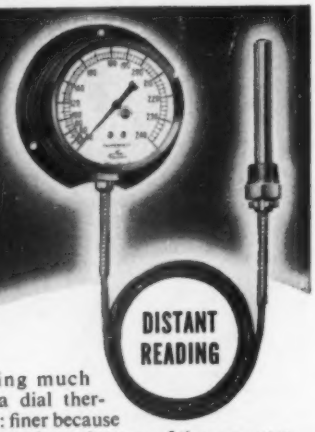

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DESIGN LITERATURE

Manufacturing processes & materials for engineers

DOYLE, MORRIS, LEACH & SCHRADER. Prentice-Hall Inc, Englewood Cliffs, N. J. 6¼ *x* 9¼, 797 *pp.* $15.00.

This is a textbook that emphasizes the technical and economics approach to manufacturing processes. The initial part covers fundamentals of metallurgy, metal cutting, forming and grinding as well as statistical concepts in measuring and gaging. It discusses automation from the theoretical as well as the practical standpoint and includes the principles of fixed and selectable programming, self regulation, feedback and numerical and analog control systems. Questions at the end of each chapter give exercises in applying the basic engineering principles.

Linear algebra

PROF G F HADLEY. Addison-Wesley Publishing Co, Inc, Reading, Mass. 6¼ x 9¼, 290 *pp.* $6.75.

Because many problems resolve to a set of simultaneous linear equations, it is valuable to have a systematic method for dealing with such sets. This is the role of linear algebra. It supplies the methods for finding a theoretical result for these equations and provides the simplified notation for their manipulation. The methods are applicable to all linear models; economic models, linear circuits, regression analysis, and linear programing are typical examples. The book is not intended for pure mathematicians but rather for those who are interested in applying the method to practical problems. Distinctive features of the text are a chapter on convex sets; a discussion of inverting a matrix by partitioning and the product form of the inverse; and a discussion of basic solutions to sets of linear equations.

Boolean algebra and its applications

J ELDON WHITESITT. Addison-Wesley Publishing Co, Inc, Reading, Mass. 6¼ x 9¼, 182 *pp.* $6.75.

Boolean algebra is explained in this quote from Augustus De Morgan: "That the symbolic processes of algebra, invented as tools of numerical calculation, should be competent to express every act of thought, and to furnish the grammar and dictionary of an all-containing system of logic, would not have been believed until it was proved in *Laws of Thought*" (by George Boole, 1815-1864).

This book starts at the beginning and presumes no more than a knowledge of algebra. Its applications in engineering are many: control-system designers use Boolean algebra to develop logic circuits with the fewest number of elements. A single notation is used throughout and emphasizes the similarities between sets, logic, and circuit problems.

Other books of interest

US aircraft, missiles and spacecraft 1961

National Aviation Education Council, 1025 Connecticut Ave NW, Washington 6, DC. 8½ *x* 11, 156 *pp.* $1.50

Low temperature research on materials

SB-451. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8 *x* 10½, 28 *pp.* 10¢

A bibliography including material from period 1943-59.

Standards and specifications—documentation symbols and abbreviations

Standards Press, 8417 *Reading Ave, Los Angeles* 45. 8½ *x* 11, 10 *pp.* $1.50.

High temperature hydraulic fluids

PB 161965. *L. R. Drane, R J. Benzing Office of Technical Services, US Dept of Commerce, Washington 25, DC.* 8½ *x* 11, 16 *pp.* 50¢

ABSTRACTS

Visual indicators

This 2-part article (second part in Oct issue) is concerned with the design of indicator dials and scales for general industrial purposes, where an accuracy, in quantitative terms, of ±1% of maximum scale values will be required.

"Design of Visual Indicators Part I," by John Spencer, University of Bristol. Engineering Materials and Design, Sept 1961, *Drury House, Russell St, Drury Lane, London, WC* 2, *England.*

The bending of angle sections

Because of the complications due to asymmetry it is normally a lengthy process finding the maximum stress in angle sections subject to bending. The author puts forward a quick method of approximating this stress.

"The Bending of Angle Sections," by J. Jennings, Mechanical World, Oct 1961, 31 *King Street West, Manchester* 3, *England.*

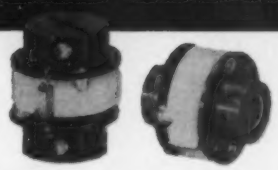
Molding high-density polyethylene

A summary of the effects of molding conditions on shrinkage, warpage, dimensional stability, dry coloring,

continued, page 133

TIC

MINIATURE FLEXIBLE COUPLINGS



FEATURE • No Backlash • Compactness and Lightweight • Accommodate both lateral and angular misalignment • Choice of types offer clamping or set-screw hubs

Type MPC-1 consists of two flanged aluminum hubs and nylon or Delrin discs with V-grooves that are displaced 90° with each other. Discs are fastened with stainless steel springs loading ball pivots against V-grooves. Dimensions ⅞ x ⅞ in.
Type MPC-2 has two cylindrical aluminum hubs, each with two ball pivots attached. Hubs are attached to a pair of flexible phosphor bronze discs which hold and load the ball pivots. Dimensions ¾ x ½ in. Both types have range of bores to accept shafts from .120″ to .250″ and meet MIL-E-4970 and withstand −80° to 200°F and shock to 100 G.

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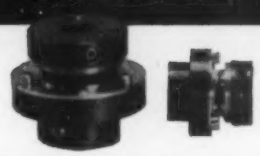

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Type ASC-1 is ⅞ x 1″
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Both are constructed of aluminum hubs, Delrin* on stainless steel clutch plates and stainless steel hardware. These rugged, high performance clutches are friction units to protect components against excessive or inertia shock loads. Range of bores to accept shafts from .120″ to .250″. These clutches meet MIL-E-4970 specs.

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How To Assure
THE MAXIMUM
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1. minimum armature transfer distance between the brake and clutch housings.
2. clutch and brake friction surfaces held to a high degree of parallelism.
3. no backlash between armature and shaft.
4. clutch and brake friction facings burnished to give rated torque on installation.
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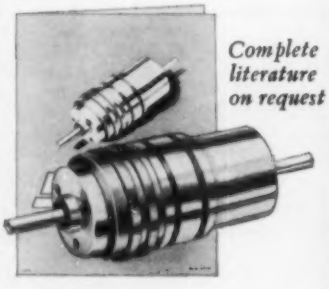
See for yourself the unique advantage of the flexible diaphragm action . . . the *only* moving part in a Simplatrol unit. Get the facts now on Simplatrol clutches and brakes.



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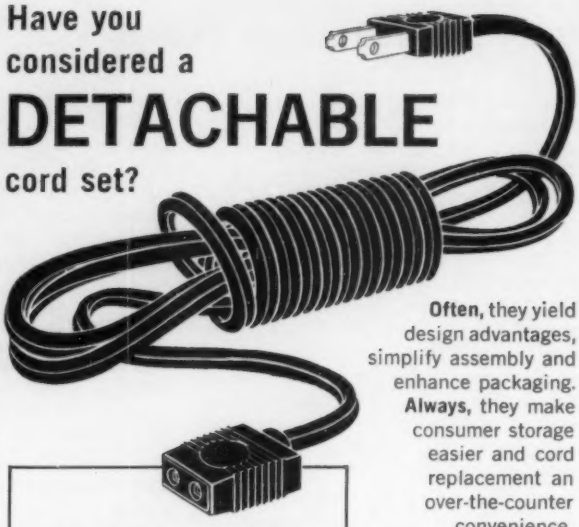
Representation in Key Industrial Areas

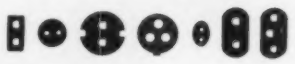
871-O

132 CIRCLE 132 ON READER SERVICE CARD

Have you considered a
DETACHABLE
cord set?



Often, they yield design advantages, simplify assembly and enhance packaging. **Always,** they make consumer storage easier and cord replacement an over-the-counter convenience. Get more information about detachable cord sets, stock cord set components and custom-engineering services offered by Miller Electric Co.



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Heat-Rem H-170 virtually fuses with hot metal surfaces . . . forms a bright finish that's resistant to moisture, mild acids, alkalis and industrial fumes. Write for full details, requesting bulletin L-9240. A-2214A

SPECO INC. Cleveland 9, Ohio

CIRCLE 50 ON READER SERVICE CARD

and the physical properties of high-density polyethylenes.

"A Guide to Molding High-density Polyethylene," by Roger B. Staub, Chemical Engineering, Union Carbide Plastics Co, Bound Brook, N.J. Modern Plastics, Oct 1961, 770 *Lexington Ave, NY* 21.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

SQUARE HEAD CYLINDERS — Bulletin SQ-61, 48 pp. Comprises specifications, dimension drawings, cutaways and design data on 1½- through 14-in. bore size, cushioned, air and hydraulic units. Tomkins-Johnson Co, Jackson, Mich.

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METALLIC GASKETS — Booklet PK-152A, 28 pp. Covers spiral-wound, metal-jacketed, flat metal, corrugated, round cross section and heavy cross section gaskets, supplying size data, cross-sections arranged according to basic design, application recommendations and max operating temperatures for standard gasket metals. Johns-Manville, Packing & Friction Materials Div, 22 E 40th St, New York 16.

Circle 341 on Reader Service Card

SELF - ALIGNING BEARINGS — Catalog, 8 pp. Furnishes properties, sizes and prices of one-piece, self-aligning, self-lubricating bronze bearings in die cast aluminum housings. Bronze Bearings Inc, 3553 Addison St, Chicago 18.

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INDUSTRIAL GAS DATA—Pocket size booklet, 48 pp. Contains conversion tables for changing volumetric information on various industrial gases from one equivalent unit of measure to another. Also provides capacity data on industrial gas delivery and storage systems and lists of volume, length and pressure conversion factors. Physical and chemical properties of oxygen, nitrogen, argon, helium, hydrogen, carbon dioxide, acetylene, neon, krypton and zenon are outlined. Air Reduction Sales Co, Div Air Reduction Co Inc, 150 E 42nd St, New York 17.

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VALVE REMOTE CONTROL — Manual 618, 28 pp. Puts emphasis on

continued, page 135

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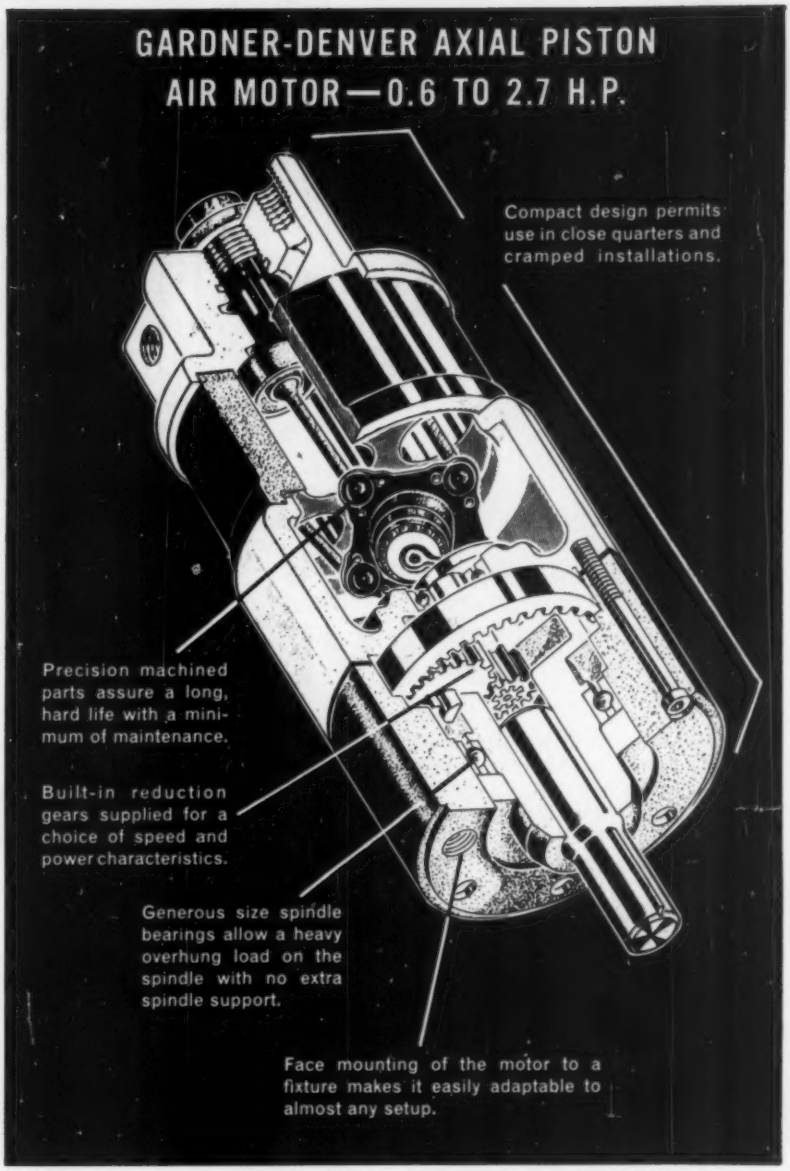
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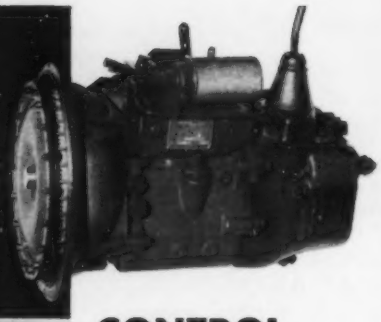

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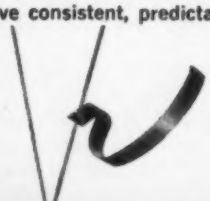

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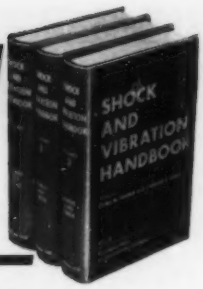

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NYLON SHAPES—Brochure, 8 pp. Covers physical properties of four grades; available sizes in nylon rod, plate, sheet, strip and tubing; and typical applications. Data on moisture conditioning, machining, bonding, welding and coloring of nylon parts is included. Cadillac Plastic & Chemical Co, 15111 Second Ave, Detroit 3.

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PNEUMATIC EQUIPMENT—Catalog 1161, 16 pp. Tabulates sizes and capacities of air valves, blenders and high capacity accoustic terminal control units. Attentuation analysis, plus suggested specifications, is included. Carnes Corp, Verona, Wis.

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POLYACRYLATE RUBBER—Bulletin AR-1, 6 pp. Spells out typical and special properties, typical applications, product characteristics, compounding and processing, effects of heat aging and oil immersion and prices. Thiokol Chemical Corp, 780 N Clinton Ave, Trenton 7, NJ.

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INSTRUMENT COUNTERS—Catalog 400, 16 pp. Deals with mechanical and electrical units used as digital readout indicators, providing dimensions, dimension drawings, general and material specifications and application data. Durant Mfg Co, 1938 N Buffum St, Milwaukee 1.

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EPOXY RESINS—Folder 7383, 4 pp. Compares 17 epoxy resins, their components, primary uses, handling characteristics, and physical and electrical properties. Mitchell-Rand Mfg. Corp, 51 Murray St, New York 7.

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RUBBER SEALS AND GASKETS—Brochure SRC-6120, 8 pp. Describes characteristics of o-rings, vibration mounts, rubber-to-metal bonded seals, diaphragms, gaskets and custom molded parts. Laboratories and facilities are discussed and illustrated. Stillman Rubber Co, 5811 Marilyn Ave, Culver City, Calif.

Circle 353 on Reader Service Card

ABS THERMOPLASTIC RESINS—Catalog 10240, 8 pp. Covers materials' combination of toughness, hardness, rigidity, chemical resistance, electrical properties, weight, color range, dimensional stability and processability. Includes chart on mechanical, physical and thermal properties of nine grades. Marbon Chemical Div, Borg-Warner Corp, Washington, W Va.

Circle 354 on Reader Service Card

MICA PRODUCTS—Brochure 27, 16 pp. Reviews effective and potential uses of mica in number of applications. Mica forms, including adhesives, tubing, and tapes, are described. Macallen Co Inc, Newmarket, NH.

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Here are the answers to the problems on page 110.

1. $x^2 - 2xy - y^2 = c$

2. $y = x^2 - \dfrac{e^{\frac{2x^3}{3}}}{\int e^{\frac{2x^3}{3}}\, dx + c}$

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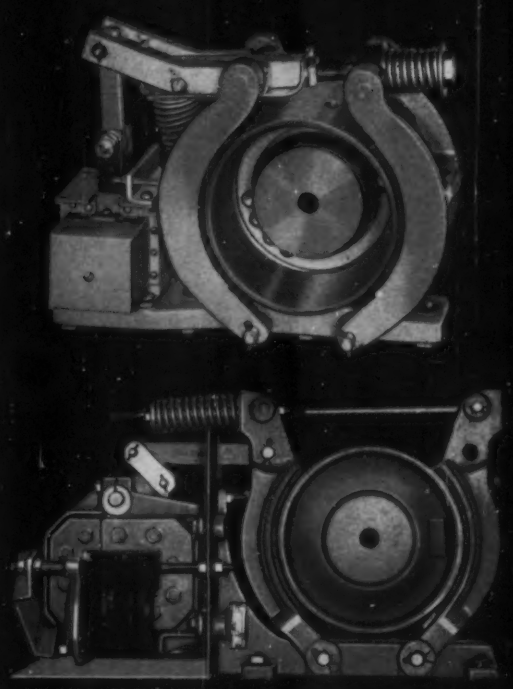

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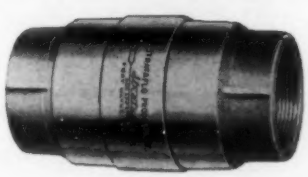

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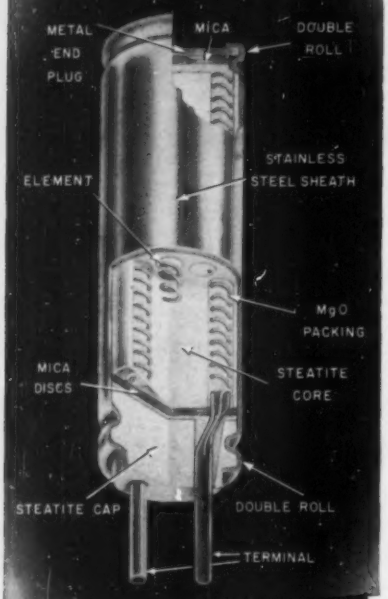

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329—Vacuum-deposited Metal Films
330—Adhesive Film
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335—Heat-reactive Hydrocarbon Resin

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305—Precision Rotary Switches
307—Gravity-sensing Potentiometer
312—Displacement Transducer
314—Single Reduction Gearmotor
316—Counterclock Combination
323—Sub-miniature Limit Stops
324—Variable Foot Switch
327—Counter Assembly

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303—Rate Transducer
305—Precision Rotary Switches
307—Gravity-sensing Potentiometer
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310—Mercury Switch Holder
313—Pressure Change Separates Magnates
316—Counter-clock Combination
317—Flexible Terminal Block
321—Close-mounting Lamp Assembly
323—Sub-miniature Limit Stops
324—Variable Foot Switch
326—AC Multi-pole Latch Relays
327—Counter Assembly

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311—Valve Minimizes Line Shock
313—Pressure Change Separates Magnets
318—Hydraulic Cylinders
319—Right Angle Check Valve
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4	27	50	73	96	119	142	165	212	235	304	327	350
5	28	51	74	97	120	143	166	213	236	305	328	351
6	29	52	75	98	121	144	167	214	237	306	329	352
7	30	53	76	99	122	145	168	215	238	307	330	353
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9	32	55	78	101	124	147	170	217	240	309	332	355
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15	38	61	84	107	130	153	200	223	246	315	338	361
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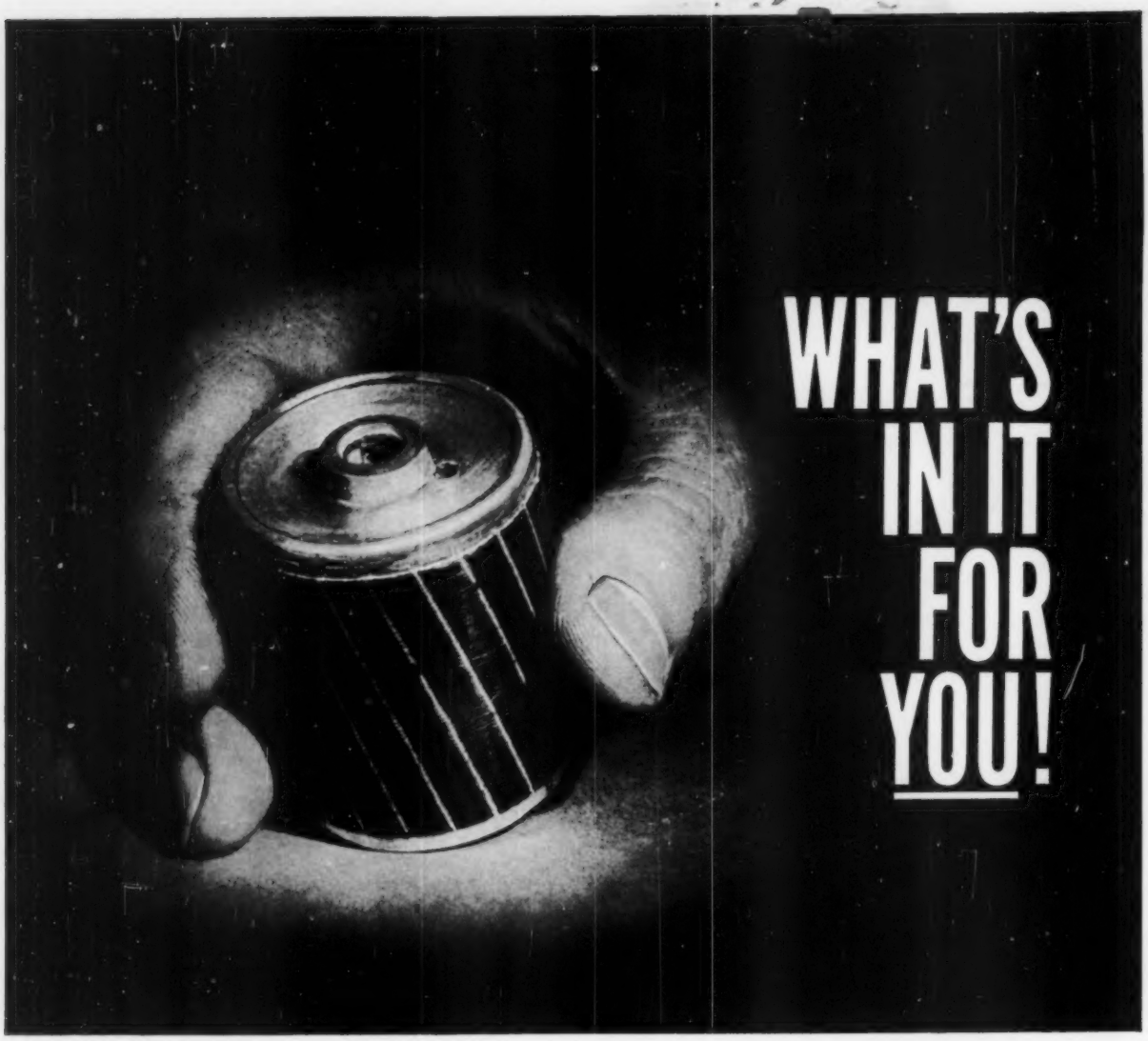

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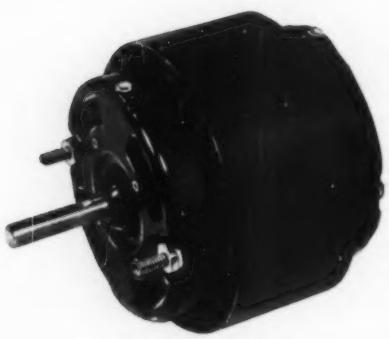

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